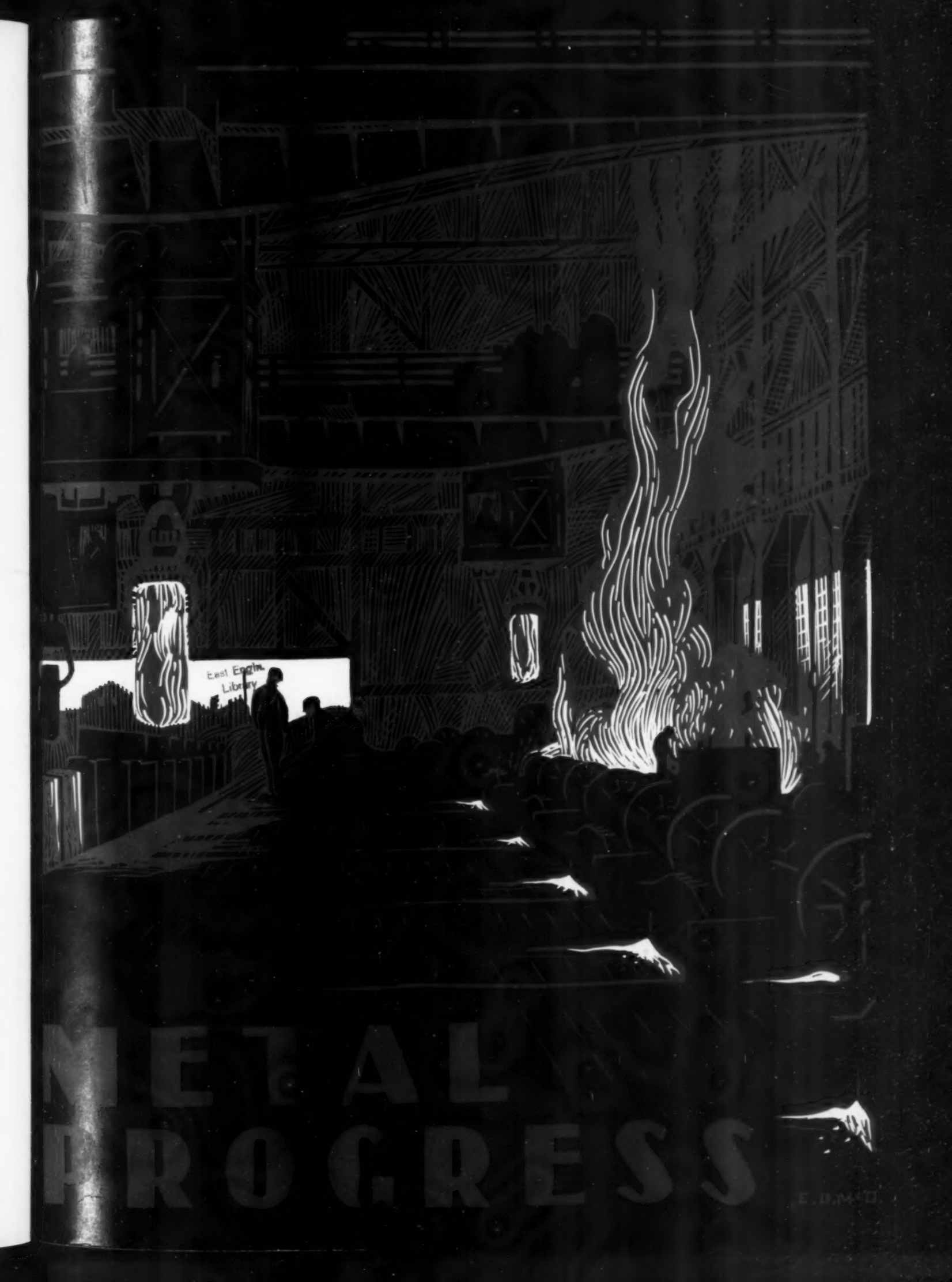
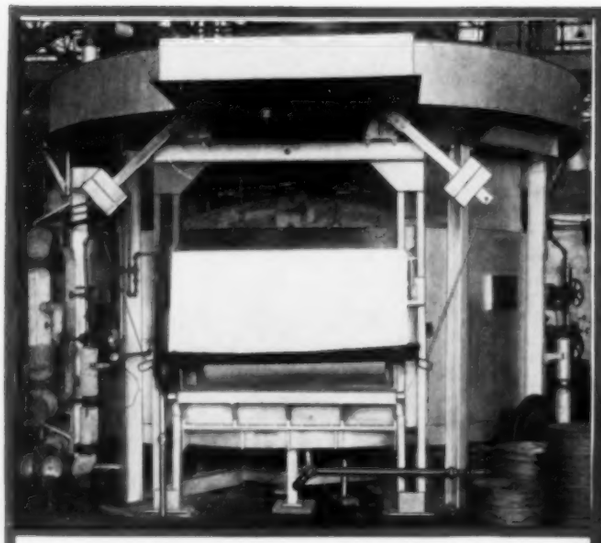
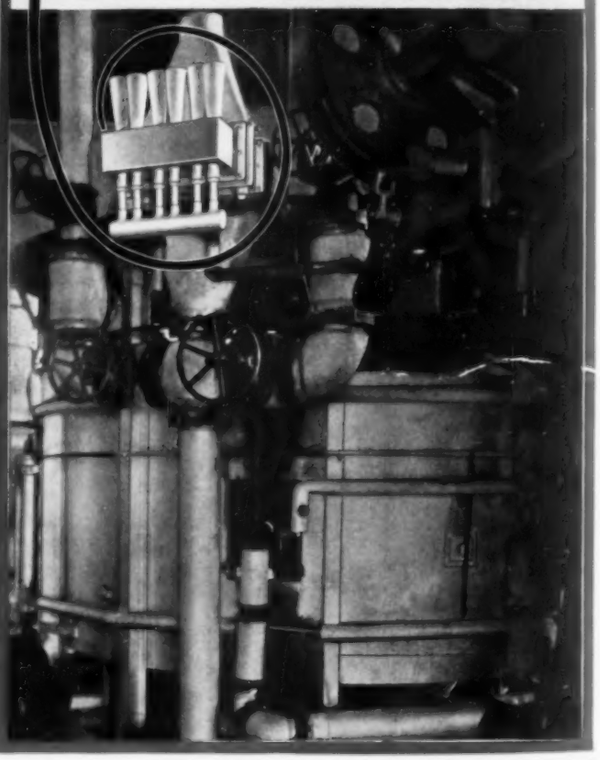

East Engin.
Library
METAL
PROGRESS



ROTARY FORGING FURNACE FOR HEATING BRAKE DRUM BLANKS EQUIPPED WITH

Air Preheater



This is one of two oil fired SC Rotary Forging Furnaces recently installed by this manufacturer. Each furnace is heating 225 brake drum blanks per hour weighing 11.2 lbs. each, from atmosphere to 1750 deg. F., with an average oil consumption of 16.5 gallons per hour.

Blanks are heated on the hearth which has a diameter of 10 ft. 6 in.

SC Air Preheaters deliver air, heated by waste gases from the furnace to approximately 500 deg., to the oil burners, greatly increasing the efficiency of the furnace, and effecting a 15% saving in fuel.

SC Air Preheaters are applicable to batch and continuous furnaces. They may be ideally suited to your own furnaces. Investigate.

Surface Combustion Corporation

TOLEDO, OHIO

Sales and Engineering Service in Principal Cities

For Any Heat Treating Operation

In addition to a complete line of Standard Rated Furnaces and Standard Burner Equipment, Surface Combustion designs and builds furnaces for either batch or continuous Carburizing, Hardening, Drawing, Annealing, Galvanizing, Forging. Also controlled Atmosphere furnaces for bright annealing of ferrous or non-ferrous metals, for gas carburizing, forging, nitriding or clean hardening of steel—for either batch or continuous operation.

Ernest E. Thum
Editor

August, 1934
Vol. 26 No. 2

METAL PROGRESS

table of contents

ELECTRIC STEEL 16
Striking drawing by an unusual technique of an operation which never fails to attract even the old timer.

GRAIN SIZE 17
A metallurgical engineer on the staff that first discovered the importance of fine and coarse grained steel for upset and machined parts summarizes a great mass of information gleaned from the shop.

DESIGN 23
Otto Kuhler, engineer and artist, whose etchings are well known to readers of Metal Progress, tells what a designer and stylist can do for mass production.

SOUND FORGINGS 26
Mr. Ashdown, who reopened a discussion on flakes—that serious defect that plagued American ordnance makers during the War—summarizes the facts brought out in recent articles and letters on the subject.

COPPER 30
Many good published micros of slip planes are of specimens strained after polishing, but this one is of drawn wire properly polished and etched.

POLISHING 31
Unconventional methods for preparing metallographic specimens which are not only rapid but develop the microstructure excellently.

BRASSES 35
A summary of extensive laboratory work on the strength and workability of non-ferrous sheet and strip and a correlation of old and new testing methods therefor.

DENTISTRY 41
After reading Dr. Skinner's article on the modern alloys and heat treatments used by the dental profession for "restorations", a toothache will undoubtedly be just as acute!

CURRENT LITERATURE 48

TRADE PAMPHLETS 54

ADVERTISERS 64

Great plans are in the making for the October issue, to be in the mails ten days prior to the opening of the National Metal Congress and the Annual Convention. It will be ten magazines in one, each in its own cover, each reviewing recent progress in one branch of the metal industry. Is your Company to be adequately represented?

Metal Progress Is Owned by

AMERICAN SOCIETY for METALS

Published and Copyrighted, 1934, by the American Society for Metals (formerly American Society for Steel Treating), 7016 Euclid Avenue, Cleveland, Ohio. Issued monthly; subscription $5 a year. Entered as second-class matter, Feb. 7, 1921, at the post office at Cleveland, O., under the Act of March 3, 1870 . . . . American Society for Metals is not responsible for statements or opinions printed in this publication.

All these Parts are made of TIMKEN STEEL

GOOD WILL BASED ON GOOD STEEL

Alloy steels suitable for the heavy-duty automotive and aircraft parts shown here vary considerably in performance characteristics and fabricating requirements, but the Timken line includes them all.

If you manufacture similar units or any other parts calling for exceptional forging, machining, heat-treating and service qualities, you will find Timken Alloy Steels of distinct value in helping you to reduce your production costs, and at the same time increase the safety factor and life of your product.

The chemical, physical and metallographic properties necessary to produce the most satisfactory results in every type of part are developed to a high and uniform degree in Timken Steels. Timken quality control includes every modern precaution to assure the continuance of those properties.

May we have the privilege of discussing your requirements with you? Timken metallurgists are available for consultation at all times.

THE TIMKEN STEEL AND TUBE COMPANY, CANTON, OHIO

District Offices or Representation in the following cities: Detroit Chicago New York Los Angeles Boston Philadelphia Houston Buffalo Rochester Syracuse Tulsa Cleveland Erie *World's Largest Producer of Electric Furnace Steel*

TIMKEN ALLOY STEELS

ELECTRIC FURNACE AND OPEN HEARTH • ALL STANDARD AND SPECIAL ANALYSES

"WE ORDER EVERYTHING FOR OXWELDING AND CUTTING FROM LINDE"

Linde Process Service

HELPS ORGANIZE OXWELDED PRODUCTION OF FIELD HOE

• *By oxwelding this bi-metal hoe the manufacturer can select each material for the specific job it is to do.*

THE experience of this Linde customer shows how Linde Process Service helped improve a small but important tool of agriculture.

"Until recently we made a field hoe by forming from a single piece of steel. The equipment for the necessary forging and rolling operations represented a considerable investment. The material was a compromise, not the best for either the blade or the shank. We redesigned to make a bi-metal job: the hoe blade of a steel made to hold its cutting edge longer; the shank of a steel selected for its ability to withstand shock and fatigue. Realizing the success of our new hoe would depend on the joint, we called on Linde Process Service to help us develop it.

LINDE OXYGEN
. . . plants and warehouses in all industrial centers.
PREST-O-LITE ACETYLENE
. . . the standard for well over a quarter of a century.
UNION CARBIDE
. . . sold in the familiar Blue and Grey drum from over 250 warehouse stocks.

OXWELD APPARATUS AND SUPPLIES—Oxweld offers the maximum value in oxy-acetylene equipment. Blowpipes, regulators, acetylene generators, welding rods, and supplies—are available for every welding and cutting operation. Complete stocks and service stations are located in all principal cities.

"The Linde organization suggested oxy-acetylene welding with bronze and helped us design and make jigs to hold the parts during welding. Improvements also were suggested in our production routine. Our new hoe has been a wonderful success. To make it we require only the simplest equipment. Our costs are lower and we make them faster."

Why not supplement the work of your engineers with Linde Process Service. Perhaps you, too, can organize your welding operations for greater speed, dependability and profit.

The nearest Linde Sales Office will be glad to serve you. Telephone or write today.

THE LINDE AIR PRODUCTS COMPANY

Unit of Union Carbide and Carbon Corporation

126 Producing Plants UCC 859 Warehouse Stocks

IN CANADA, DOMINION OXYGEN CO., LTD., TORONTO

LINDE OXYGEN • PREST-O-LITE ACETYLENE • OXWELD APPARATUS AND SUPPLIES • UNION CARBIDE

PRODUCT OF A UNIT OF UCC UNION CARBIDE AND CARBON CORPORATION

Users of products and processes developed by Units of Union Carbide and Carbon Corporation benefit from a most unique coordination of scientific research with manufacturing, sales and service facilities. You are cordially invited to visit this summer the numerous exhibits sponsored by the Corporation in both the Basic and Applied Science sections in the Hall of Science at Chicago's 1934 A Century of Progress Exposition.

Sales Offices:

Atlanta	Houston	Portland, Ore.
Baltimore	Indianapolis	St. Louis
Birmingham	Kansas City	Salt Lake City
Boston	Los Angeles	San Francisco
Buffalo	Memphis	Seattle
Butte	Milwaukee	Spokane
Chicago	Minneapolis	Tulsa
Cleveland	New Orleans	
Dallas	New York	
Denver	Philadelphia	
Detroit	Phoenix	
El Paso	Pittsburgh	

NRA

A Heat of Electric Steel

The scratchboard drawing above is an adaptation of the old wood-cut technique to modern black and white illustration. This drawing was first made in black and white from a photograph and then transferred to a blackened cardboard and the essential lines scratched in, giving a study in shadows, full black and full white.

Courtesy Timken Steel and Tube Co

By R. L. Wilson
Metallurgical Engineer
Timken Steel & Tube Co.
Canton, Ohio

GRAIN SIZE IN STEEL

some of the practical aspects

WHEN steels are heated above their transformation range it is expected that grain growth will occur, and the higher the temperature and the longer the time, the larger the crystals will become. However, it is well known that some steels coarsen in structure quite rapidly on overheating, while others show sluggish grain growth. The steels exhibiting marked increase in grain size on heating (within the temperature limits for commercial heat treating operations) have been called "coarse grained." Steels characterized by but little grain growth at these temperatures have been designated as "fine grained."

Since the phenomena of crystal growth in metals involve both time and temperature, it might be preferable to think of coarse and fine grained steels as materials possessing different *rates* of grain growth. The coarse grained steels would then be described as having a faster rate of grain growth than the fine grained steels for any particular conditions of heating. All steels could be classified on this basis if the proper distinction were observed between (*a*) the rate of change of the grain size with time at a given temperature, and (*b*) the rate of change of the grain size with temperature for a fixed time of heating.

For any steel there is always some high temperature at which brief or prolonged heating will cause marked grain growth. As a consequence, the classification of steels as coarse grained or fine grained must be qualified by a statement of the conditions of heating.

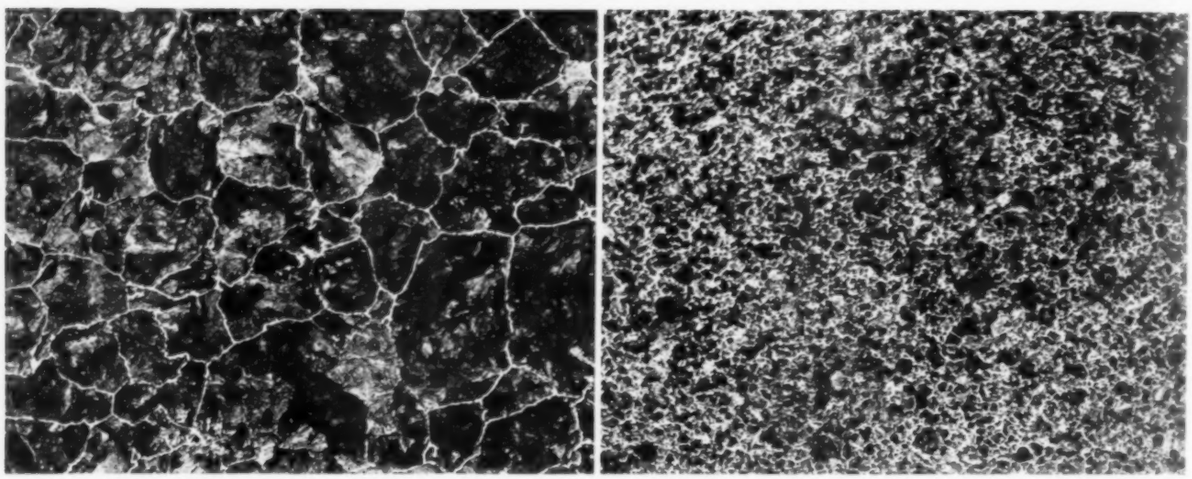
Determination of Grain Size — The commonly accepted method of determining the grain growth characteristics of a steel is to measure the size of the austenite grains that constitute the structure after a sample has been heated eight hours at 1700° F. In view of the technical difficulties of direct measurement at 1700° F. it became necessary to devise some means of tracing, in the structure of the steel at ordinary temperatures, the extent of the austenite grain size that had existed at the end of the heating period. Heating the sample at 1700° F. in an active carburizing medium offered the best solution of the problem; during carburizing the austenite grains at the surface of the sample become saturated with carbon, and on slow cooling these grains are no longer able to retain all the carbon they have dissolved, whereupon the excess carbon is precipitated as carbide, which gathers at the boundaries of the austenite grains to form the familiar cementite network. The meshes or openings in the carbide network thus correspond to the original austenite grains and can be examined at leisure with the metallographic microscope.

Grain Size Classification of Steels — This procedure is the basis of the carburizing test for determining the grain size of steel. Sam-

ples are carburized eight hours at 1700° F. to obtain a hyper-eutectoid case. The boxes are cooled slowly from the carburizing temperature and specimens are prepared from the samples for microscopic examination. The number of grains found in one square inch of the structure as viewed at 100 diameters magnification serves as the index of the grain size.

depending upon the physical properties and the manufacturing requirements that are to be emphasized.

Transformation and Hardening — In order to understand their behavior in heat treating, the nature of the changes on heating and cooling through the transformation range must be recalled. During heating past the critical tem-



Appearance of Structures Having No. 3 Grain Size (Coarse Grain) and No. 8 Grain Size (Fine Grain) Respectively. Carburized, box cooled, etched with nital, and photographed at 100 diameters magnification

Several charts have been proposed to assist in evaluating the grain size of steel. The A.S.T.M. Grain Size Classification Chart, for instance, covers all classes of steels by eight numbers. No. 1 grain size indicates the structure having one grain per square inch in the carburizing test when magnified 100 diameters; No. 2 grain size has two grains per square inch; No. 3, four grains and so on by geometric progression to No. 8 grain size, which has 128 or more grains per square inch.

For practical purposes the grain size numbers 1 to 5 may be grouped together to comprise the coarse grained steels, numbers 6 to 8 the fine grained steels. Representative samples are shown in the cuts on this page.

Because of the conspicuous differences in the character of the coarse and fine grained steels, the matter of grain size has received considerable attention. Grain size influences the behavior of steel in forging, annealing, machining, and hardening as well as the mechanical properties at normal and elevated temperatures. Both kinds of steels have definite fields of usefulness,

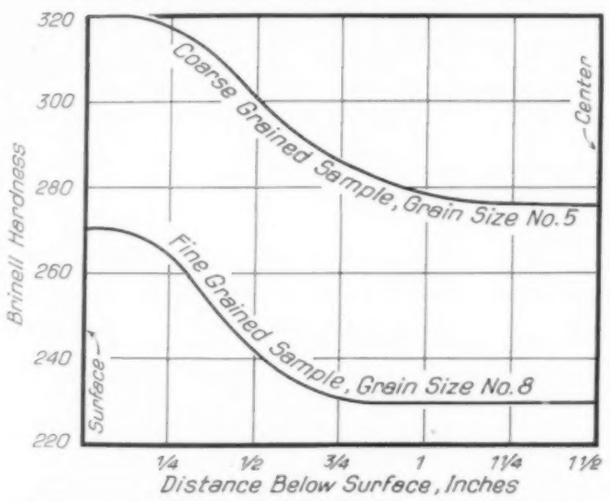
perature the steels are governed by the grain growth tendencies already described, which determine the grain size of the resulting austenite. At one time it was supposed that these austenite grains, regardless of their size, always transformed identically on cooling. More recently, some valuable researches by E. C. Bain have demonstrated that the austenite grain size prior to transformation affects not only the temperature at which austenite is converted into pearlite, but also the speed. The coarse grained steels transform at a slightly lower temperature than the fine grained steels and at a relatively slower rate, which permits the transformation to extend over a longer time interval. The fine grained steels develop a faster reaction velocity and transform more quickly. (In the heating and cooling characteristics of the coarse grained steels, there is an advance suggestion of the low hardening temperatures and the restricted hardening ranges employed in quenching materials of this class.)

The usual purpose in quenching steels is to produce maximum hardening and grain refine-

ment. With this object in view, the coarse grained steels would have to be quenched from a temperature just above their upper critical point, otherwise the structure would be coarsened. The fine grained steels, on the contrary, can be heated considerably higher than their transformation range without defeating the purpose of the refining treatment, and this means that they have a broad hardening range, which is a distinct commercial advantage.

The slower transformation rate on cooling, exhibited by the coarse grained steels, makes them essentially deep hardening in character, while the fine grained steels are shallow hardening owing to their more rapid transformation. Adjoining curves indicate this clearly. The coarse grained steels also harden to a greater intensity of surface hardness and possess more uniform deep hardening qualities than fine grained steels of like chemical composition. In a sense, coarse grain size can be reckoned as a hardening element in estimating the potential hardening capacity of a steel.

Coarse-Grained Steels Harden More Deeply Than Fine-Grained Steels. This relation is brought out in 3-in. rounds of a 0.40% carbon manganese steel which has been normalized at 1600° F., water quenched from 1500° F., and air cooled from 1000° F.



Although the fine grained steels are apt to show lack of hardening power, this shortcoming is to some extent compensated by the reduced warpage and smaller residual hardening stresses associated with milder quenching.

Fine Grained Carburizing Steels — Grain size is of utmost importance in the case hardening of fine grained alloy steels, where the case and core structures are not seriously coarsened after carburizing at 1650 to 1700° F. for quite long times. Consequently, the double quenching treatments for refining first the core and then the case are unnecessary. There are several ways in which heat treating economies may then be introduced, depending upon the design of the parts being manufactured, the service requirements, and the mechanical properties to be maintained in the case and core.

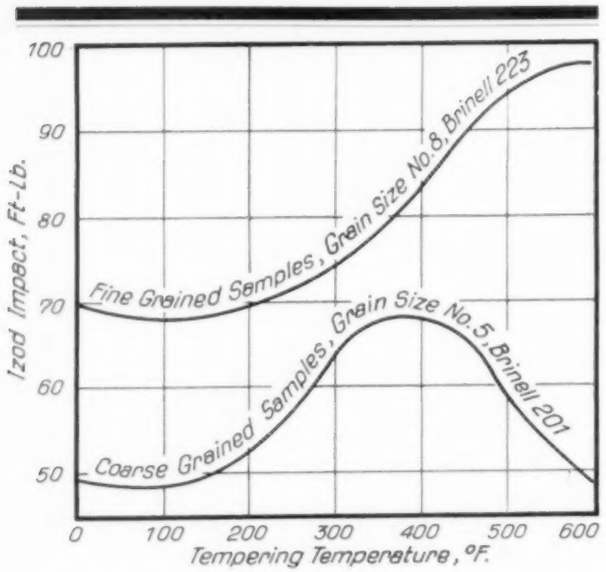
Sometimes plant equipment or conveniences are responsible for the choice of the hardening practice. In general, however, carburized articles are cooled slowly from the carburizing heat and given a single refining quench when there is danger of warpage due to complicated design or radical changes in section and mass. Excess carbide existing in the case and the ferrite in the core can be properly put into solution by adjusting the quenching temperature.

Whenever conditions permit the work to be quenched directly from the carburizing heat, it is considered good policy to impose an additional single refining quench to obtain the best stability and endurance of the case. Direct quenching produces a desirable dispersion of the carbide particles in the case, and the properties of the core can be balanced by changing the temperature of the final quench.

Of course, the simplest heat treatment for case hardened parts consists in quenching the steel directly from the carburizing heat without subsequent treatment. Careful study of requirements and close observation of parts in service have justified this as being adequate for many applications. For instance, it is probably the best that can be employed on automotive differential and transmission gears.

Direct Hardening Steels — Besides being more economical in case hardening, the fine grained steels are inherently tougher than the coarse grained steels. The curves and table on page 20 show that, when compared at the same tensile strength or hardness, or after equally effective heat treatment, the fine grained steels are superior in impact resistance. The medium carbon and higher carbon steels also share this property. A definite place exists for such fine grained direct hardening steels in applications requiring materials having good shock value or showing small dimensional changes in the hardening process.

The coarse grained direct hardening steels are sometimes selected for deep hardening, which



Fine-Grained Cores Are Tougher Than Coarse-Grained Cores. Steel is S.A.E. 4615, case hardened, 1-in. round bars, double quenched in oil from 1525 and 1420° F. and then tempered as shown

ture produced by normalizing or annealing. That structure in turn depends upon the arrangement of the carbides within the pearlite grains. It is recognized that large grained lamellar pearlite represents the proper form of the carbides for best cutting efficiency and machining finish.

Partially and fully spheroidized structures, while being less desirable from the standpoint of machinability, are frequently unavoidable. However, certain steels (such as S.A.E. 1095, in which lamellar pearlite forms readily on annealing) are hard enough in the lamellar condition to reduce the life of machine tools simply by wear. The logical alternative in such a case is to lower the hardness of the steel by spheroidizing the carbides. Other steels tend toward spheroidization on account of alloying elements in their chemical composition.

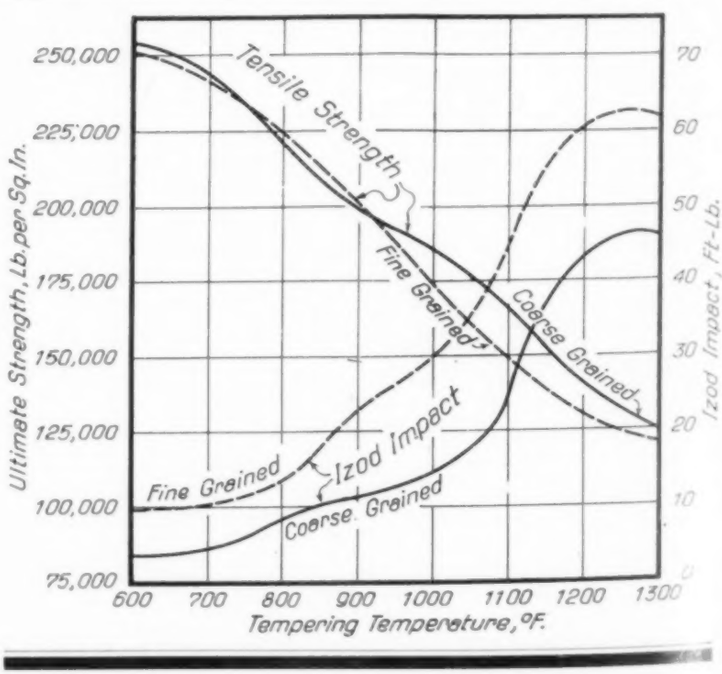
Grain Size vs. Properties of Mn-Mo Steels

	Steel E	Steel F	Steel G	Steel H
Chemical composition				
Carbon	0.25	0.28	0.37	0.38
Manganese	1.48	1.54	1.73	1.73
Silicon	0.16	0.22	0.18	0.25
Molybdenum	0.20	0.25	0.23	0.20
Grain size	5	8	5	8
Mechanical Properties, 1 In. Bars, Water Hardened & Tempered				
Yield strength	115,300	116,000	144,100	145,000
Ultimate strength	128,800	129,000	159,300	159,500
Elongation in 2 in.	20.6%	21.0%	18.0%	18.2%
Reduction of area	63.2%	66.7%	56.6%	57.1%
Izod impact	74.5	91.1	55.3	64.2
Brinell hardness	269	269	321	321

Hardened Steel Is Tougher if Fine-Grained. 0.50% carbon manganese molybdenum steels were quenched in oil from 1525° F. and tempered as shown. Those with the fine grain had notably higher Izod impact values

makes them suitable for pieces of large size and mass that are to be heat treated to specified physical limits. More often, the easy machining of the coarse grained steels is the principal inducement, as for example when parts receive a number of machining operations or must satisfy certain standards of machining finish. Here again is a significant connection between grain size and manufacturing costs, for ultimately the machinability of steel is considered in terms of tool life and volume of production; coarse grained steels are being widely used in direct hardened automotive transmission gears for the economy in machining.

Annealing and Machining — Machinability is related to microstruc-

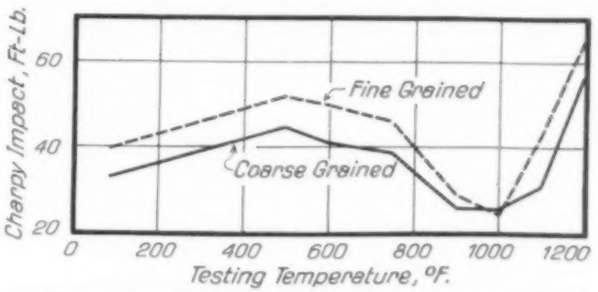


The observations already made regarding the coarse and fine grained steels would forecast a difference in the character of the normalized or annealed structures, with consequent effect on the machinability. Many of the coarse grained steels can be normalized or annealed to a lamellar pearlitic structure of reasonably low hardness. The fine grained steels under any circumstances are apt to show spheroidized carbides after the conventional softening treatments.

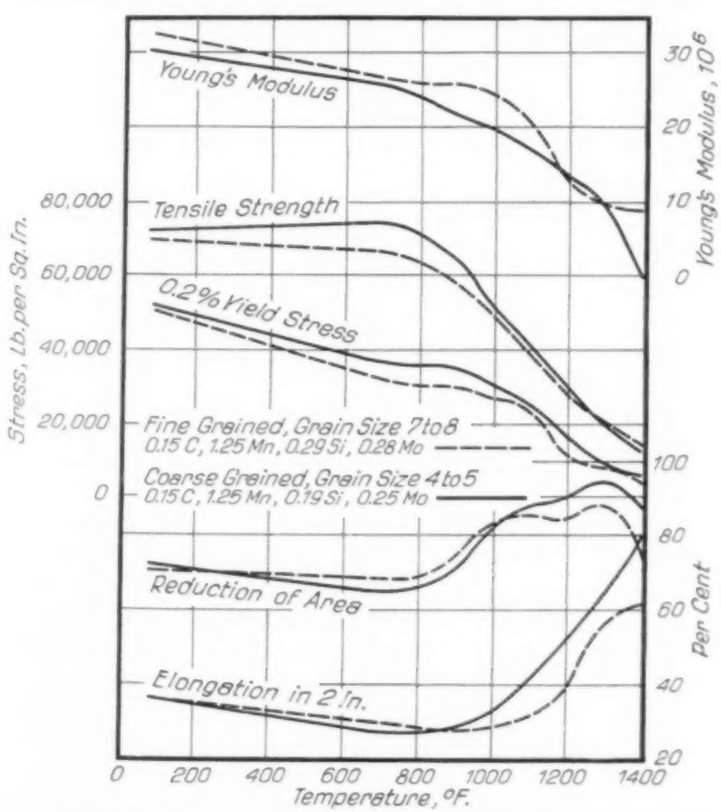
Formation of lamellar pearlite is definitely assisted by coarse austenite grain size. In this respect, the coarse grained steels have an inherent advantage to machining operations, although the fine grained steels can acquire this character temporarily if they are deliberately heated to very high temperatures to promote grain growth. By this means the rather unsatisfactory machinability of the fine grained low carbon alloy steels can be redeemed.

The advisability of adopting normalizing or annealing temperatures as high as 1700 to 1850° F. for the fine grained steels should be decided by balancing the additional expense of the extraordinary heat treatment with the reduction in cost of the machining operations. In those instances where a high temperature treatment is economical, it is possible to maintain all the advantages of the fine grained steels in hardening and physical properties without making a great sacrifice in machinability.

Toughness of Hot Steel Depends on Grain Size. These samples of carbon-molybdenum steel were held at heat 1 hr., transferred to the testing machine rapidly and broken while hot



Short Time Tensile Tests on Mn-Mo Steel, Fine and Coarse Grain



High Temperature Properties— The higher impact strength of the fine grained steels at atmospheric temperatures has already been mentioned. At elevated temperatures the fine grained steels continue to show somewhat better shock resistance than the coarse grained steels of the same composition and initial physical condition. This is shown in the adjoining curves.

Whenever a spheroidized structure in the steel is anticipated or is the object of the annealing treatment, the fine grained steels are preferable.

There are small differences in the short time tensile properties up to 1000° F., although they do not appear noteworthy because a short time at the high temperature is hardly sufficient to efface the influence of the original differences in the room temperature properties. Beyond 1000° F., the strength of most pearlitic steels decreases rapidly with accompanying increase in ductility. A systematic study of several steels up to 1400° F. together with a few data on materials observed at commercial forging temperatures, indicates that the fine grained steels lose strength more grad-

ually and gain ductility more slowly than the coarse grained steels.

The strength and ductility of steels at high temperature, as measured in the short time tensile test, are of interest in connection with the drop forging and machine forging processes. Whenever forgings are made of fine grained steels and the forging temperature is not high enough to cause distinct coarsening of the structure, the fine grained steels will not flow as easily as the coarse grained steels, and more hammer blows may be required to finish the forging. In the case of forgings produced by the machine forging process, the displacement of metal must be completed in several forming operations, so that the greater strength of the fine grained steels is manifested by the *power* required to make a forging.

On the other hand this very tenacity of the fine grained steels enables them to withstand rapid large reductions in forging. Engineers who design machinery for the hot working of steels speak of a steel as having a certain deforming rate for a stated pressure. For the circumstances described, the fine grained steels would be said to have a slower deforming rate at a definite temperature and pressure than the coarse grained steels.

Creep Strength vs. Grain Size of C-Mo Steels

Temperature	Grain Size	Stresses (psi.) to Produce 1% Creep in		
		100,000 Hr.	10,000 Hr.	1000 Hr.
800°F.	Coarse	15,500	26,000	44,500
800°F.	Fine	21,500	27,000	34,000
1000°F.	Coarse	10,700	17,800	29,200
1000°F.	Fine	9,600	15,800	26,000
1200°F.	Coarse	480	2,000	4,050
1200°F.	Fine	260	1,400	3,400

Obviously, if the forging temperature exceeds the coarsening temperature, the grain growth of the fine grained steels will confer upon them the same hot working qualities exhibited by the coarse grained steels.

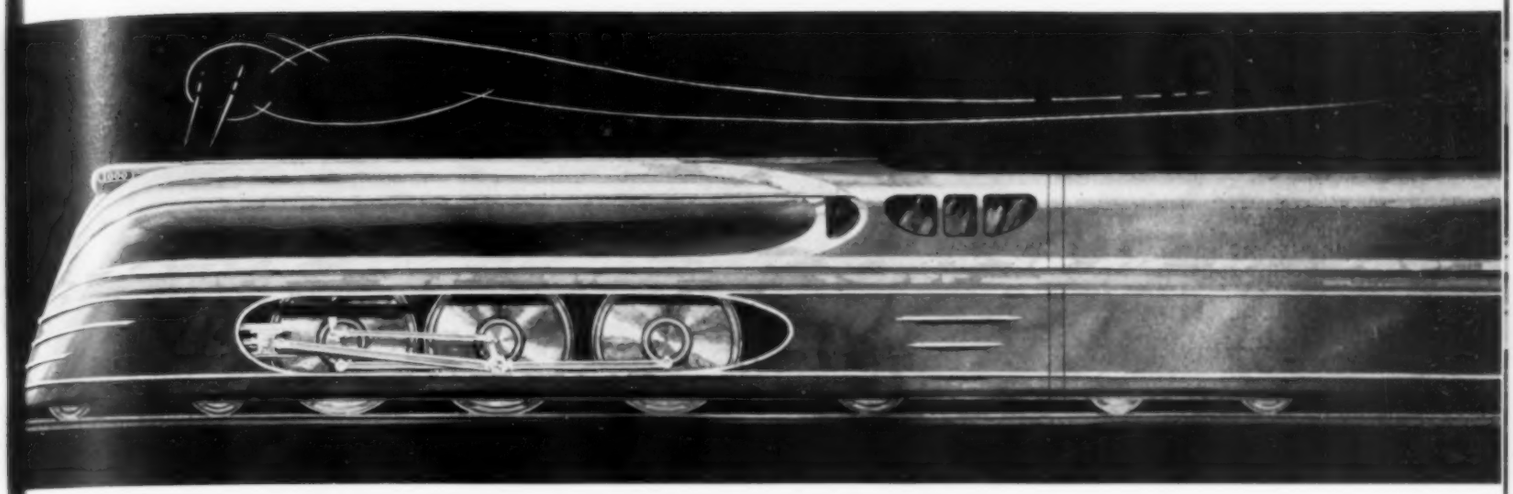
Creep, or the long time loading characteristics of steels at high temperatures, is also influenced by grain size. At temperatures below 900 to 950° F. the fine grained steels give higher creep strength for slow rates of creep than coarse grained steels of identical composition and heat treatment. On the other hand, the coarse grained steels are the stronger for fast rates of creep at low temperatures. Above 900 to 950° F. the coarse grained steels exhibit higher creep strength for all rates of flow. However, the difference is often too small to be of commercial importance. In such cases a steel would be selected with more emphasis upon the other properties.

Commercial Applications — There are many interesting individual applications for engineering purposes in which the proper choice of grain size has led to economy in manufacturing or has contributed to better performance.

For instance, by coarsening the structure of the coarse grained steels intentionally, the drilling quality and finish of rifle and machine gun barrels has been improved. Similar coarsening of the structure of rods by the patenting process prepares for the large reductions in wire drawing that are necessary to obtain the "long fiber" so desirable from the standpoint of mechanical properties. Another singular advantage of the coarse grained steels is in heat treating large pieces of steel to develop high surface hardness together with high impact strength of specimens taken half way between surface and center of the section. In such cases the coarse grained steels of simple composition are shallow hardening in relation to the size of the cross section.

Fine grained steels have been used successfully to develop greater toughness in oil hardened bolts that are required to withstand the cold bend test. In like manner the apparent transverse tooth strength of transmission gears and the transverse loading capacity of solid and hollow rollers are increased. This increase in strength is called "apparent" because it does not seem to involve any real change in the inherent strength of the steel but probably results from greater ductility, which permits the load to be distributed over a larger area of contact. Typical examples of the application of the fine grained alloy carburizing steels may be found in the manufacture of textile machinery; perforated and slotted machine parts having very thin sections are being carburized and single quenched with extremely small distortion.

In general, the coarse grained steels are recommended for good machinability, intense hardening, easy coarsening of structure, and high temperature service above 950° F. (as in oil refineries). The fine grained steels are recommended for economical case hardening, good toughness, superficial hardening of the direct hardening steels, small warpage in hardening, best mechanical properties of untreated steel, and high temperature service below 950° F. (as in steam power plants).



Streamlined Steam Locomotive Suggested by American Locomotive Co.

WHAT PRICE BEAUTY

of line and color

By O. Kuhler Industrial Designer New York

MANY manufacturers have discovered that their product is more salable if technical perfection is expressed by a well-designed outside appearance. Package design was the first notable step in this direction; improvements in containers for cosmetics and foodstuffs have been especially noteworthy. But paper or cardboard packages — even jars and bottles — are thrown away quickly and can do only one sales job by attracting the customer. To correct this condition, permanent metal boxes have appeared on the market, such as those shown on page 25.

How much more important, then, does it appear that the product itself should have lasting beauty so that it may sell itself to its owner, over and over again? How great may be the disappointment if the discriminating buyer finds in a beautiful packing only a product of mediocre appearance?

However, re-design in the metal industry is a costly job, and therefore should be most carefully done before new dies, patterns and other tools are made. Logically the manufacturer will turn to the personnel in his own plant to create a better appearance for the product, but while his engineers are equipped to do an engineering job and his salesmen know how to sell, none of them can be expected to possess a natural talent for the expression of beauty. Both engineer and salesman will be important advisers as to improved design, but neither can be creators.

It is for this reason that experimentation for improved appearance of products has turned out to be very costly in many instances, especially in the metal industry. If attempted by the old staff the best result to be expected is a compromise based on experience gained in manufacturing and marketing the old-fashioned articles. To introduce radically new ideas will seldom be attempted, yet in many cases it is a new idea that is needed most!

Turning back a few decades we find men who

were both designers and manufacturers; as skilled artisans they possessed both of these abilities. The machine and "scientific management" have practically eliminated this type of craftsman by the necessarily high specialization in all operations concerned with the production of articles of every-day use. Yet we value highly the products of an old furniture craftsman, like Duncan Phyfe; we treasure the beauty of the old Venetian glasses blown, etched and engraved by craftsmen, craftsmen in the true sense of the word.

Rarity Not Necessary

We assume, often wrongly, that their only value lies in their rarity, forgetting that if these old craftsmen had had the advantages of mass production, they most probably would have seen to it that their products were manufactured in quantities, enabling a much larger number to enjoy the beauty which they had so proudly embedded in them.

Things of beauty, fragile or rugged, have been preserved largely because their original owners recognized their inherent worth, whereas similar articles for similar purposes but possessing less intrinsic merit were carelessly handled and soon discarded as not worth saving. Even though a beautiful old object may possess a high utilitarian value, it sooner or later is taken out of practical every-day use and carefully preserved for its beauty alone. Museums now see to that!

We are aiming for better standards of living and should not forget that the enjoyment of beauty is a considerable part to this end. Today we have mass production, which should allow us to enjoy beautiful products at a price and in a quantity that the craftsmen of old never dreamed of. We possess an abundance of new materials to work in — be it in metals, cellulose, glass, or condensation products. Our opportunities are almost limitless, although unfortunately new materials have often been applied to the old lines of an old product, thinking thereby that their beauty may enhance the product itself. This is a wrong conclusion.

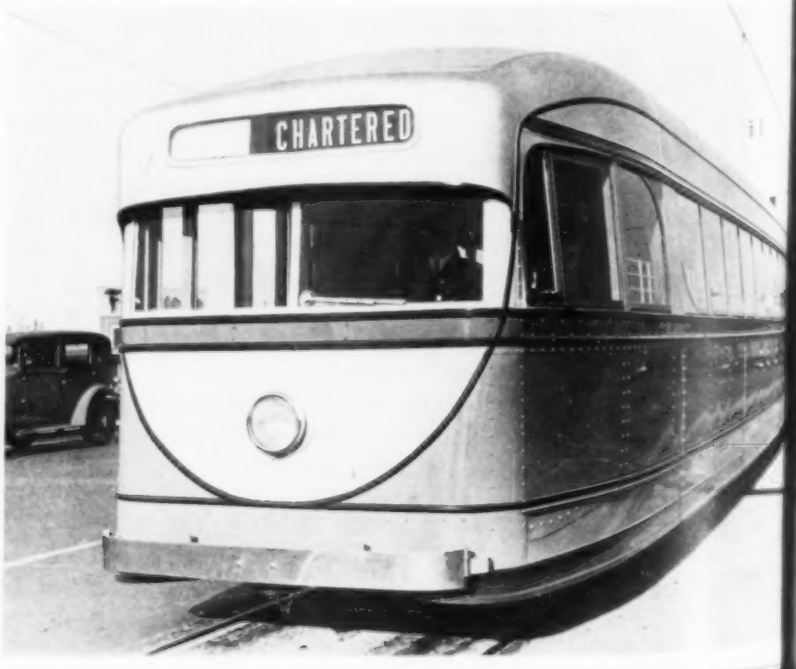
Unfortunately we have been "gilding the lily" for so long that most of us can think of beauty only in connection with ornamentation. We forget entirely that every well-conceived and technically perfect product has inherent beauty. A suspension bridge needs no ornamental fretwork! Mr. Kinkead clearly stated this premise of the industrial designer in his article on "Design and Aesthetics of Assemblies Using Welding" in last February's issue. To understand this beauty and to emphasize it by good design and correctly chosen materials is the problem now under discussion.

There is beauty and grace in a sailing yacht, solely achieved by technical perfection. There is beauty in a ball bearing, inherent in its mathematical correctness. Many of my manufacturer-friends use models of such things on their desks as paperweights, and when asked why, they invariably answer, "Because I like it." This certainly proves the unconscious aesthetic appeal of an appropriate form.

While the examples mentioned were developed by pure utility, there are plenty of products to which a mathematical solution for the attainment of beauty may not be applied; it is here that the manufacturer will have to combine with the trained artist.

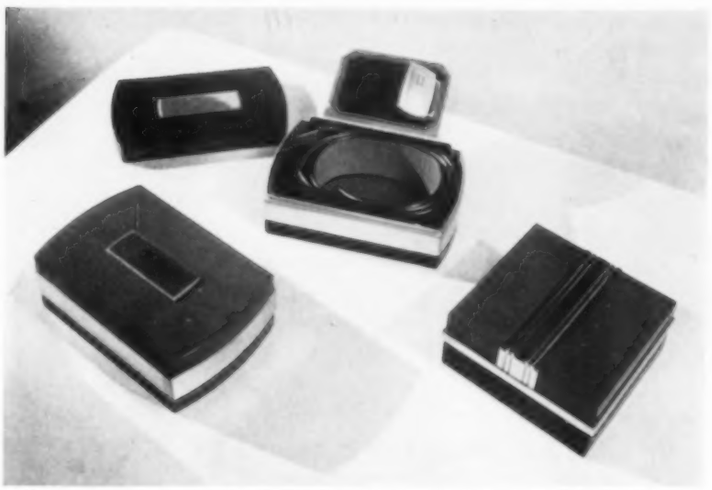
The profession of the industrial designer has been born from mass production and the desire

Streamlined Street Car Designed and Built by J. G. Brill Co., Philadelphia. T and the locomotive at the head of the article were styled by Mr. Ki



for better products to conquer larger markets. He is the man who can tell the manufacturer how to make his product look like something. He has had to travel a hard uphill road, for the terms "visionary" and "impracticable" are so often wrongly associated with the artist.

It must be clearly understood that not any artist will do, because besides a keen sense for utility the industrial designer has to have a sense of proportion and color appeal. He must be able to smooth the lines which technical convenience has given a product and emphasize by contrasts in color or material the inherent beauty of any utilitarian product, so as to make it look compact, durable, efficient, or whatever attribute might be necessary to improve its marketability. His training, therefore, should have been in engineering as well as in design. He forms an important link between the manufacturer and the buying public and has to know something of both the problems of manufacturing and selling.



Attractive Boxes Made of Zinc-Base Die Castings. Polishing, etching or lacquering lends added beauty to form and relief

Laboratories for Design

Realizing the importance of better designed products, some large manufacturers have installed their own laboratories for design. Here the newly planned product is analyzed by engineer and salesman, and the industrial designer combines both reactions and puts them effectively into the new product. Not every manufacturer, however, can afford the facility of his own laboratory. Some have called in the "free lance designer," and on account of the enlarged vision gained by handling many products for different purposes, the free lance will frequently be able to embody ideas from one design into another of entirely different character.

Strange as it may seem to some, the artist will often turn out to be a very practical inventor. Unhampered by tradition and not too strongly impressed by conventional shop practices, he is able to look at the product from a very new angle, and suggest changes that add considerably to its utility.

Fortunately, by the logical process of eliminating the unfit, able designers are now available who have succeeded in a hard fight against a lot of fakers. A supposed fog and glamor surrounding the artist have often been used as a sales point by art racketeers to bluff the manufacturer. It is therefore my contention that if the manufacturer is dealing with a designer who cannot talk shop to him, he must beware.

Does better design actually bring sales? Seek the answer in the automobile industry. It is generally taken for granted by the buyer today that the car is mechanically perfect. Many are sold without ever lifting the hood to have a look at the engine, simply by the appeal of the body design and interior fittings. And by "fittings" I do not mean spotlights, vases, or ashtrays, but a general impression of fitness arising from the arrangement of line, color and material.

Or, turn to manufacturers of household articles, like electric appliances. They have realized the necessity of appealing to feminine taste, and through industrial designers have added this appeal by simple and graceful design, where formerly there was only a hodge-podge of fancy, inefficient and senseless ornamentation.

Better design not only improves a product, but, combined with good engineering, often can save it from obliteration. Let me point to the steam locomotive as an example. Often her death knell has been sounded, but now she is emerging in a new dress, streamlined and fast to haul light-weight cars at schedules in keeping with the modern tempo. Passenger appeal as well as the publicity connected therewith has been added to its refined engineering and actual technical advantages, and it is safe to say that the locomotive can meet the competition that is offered by other types of motive power.

(Continued on page 56.)

By H. H. Ashdown
Consulting Metallurgist
Pittsburgh, Pa.

FLAKES IN FORGINGS

summary of recent discussion

AN ARTICLE on "Prevention of Flakes in Alloy Steels" appeared in METAL PROGRESS last November from the writer's pen. Since then several letters have been written to the editor on this subject and published, and he has asked me to summarize the situation and close the discussion for the present.

First, it would be well to present my credentials, in order that views which may be at variance with those of prominent metallurgists can be appraised by the reader, and this, perhaps, can be done without false modesty. The present writer has been associated with the manufacture of ordnance and marine forgings for more than 30 years. During the War period alone he was largely responsible for the production of more than 10,000 gun tube forgings of calibers from 3 to 18 in. by Armstrong Whitworth Co., an English firm with which he then was engaged.

As to the importance of this type of defect, it would appear from Mr. Margerum's account of the experiences of the U.S. Navy that the difficulties arising from it had not yet been fully discussed in print. My original article had as its main object to focus attention on the serious nature of this trouble in any finished forging of large size and to indicate the means of prevention; this has apparently been fully met.

With that same cautious attitude it may be stated that irrespective of the type of furnace used, whether acid or basic open-hearth or electric, if suitable precautions are not adopted during fabrication of the forgings, with certain of these alloy steels the "flake" problem is still with us.

Next it would be well to consider the means whereby flakes may be distinguished. Dr. Edouard Houdremont's contribution in the May issue is helpful in giving greater clarity to the distinction between them and the small ruptures which sometimes occur in the transverse tensile test specimens when highly stressed and broken at room temperature. Having seen many examples of each type of fracture, which are so distinctive, it has never occurred to me that there should be any confusion between the two. In "dirty steel," which gives either a conchoidal or woody fracture, the crystalline areas are usually much smaller and the crystal grains much finer and more sharply defined on their edges than are the true "flake ruptures."

In summarizing Dr. Giolitti's first comments, it would appear to the writer, as well as to other commentators, that he has confused flakes with such woody structure. It is true that if the latter defect is present the speed of testing may cause a premature failure of the test specimen, and in the portion infected with inclusions a different type of fracture may be observed. It does not appear, however, that the speed of testing need be considered on a "flake infected" steel. On reference to the illustrations of the fractured plate and the etched bar stock in my original article, it will be appreciated that the results on

any physical tests may be readily forecast. The bend tests in the illustrations also should be sufficiently convincing as to the question of speed of testing.

Hairline cracks, often indicative of the presence of flake, are not readily detectable on a highly polished interior surface by periscopic examination. One method of detection is to sponge the polished surface with oil, allow a period of rest, wipe off the excess oil, whitewash the surface and slightly warm the forging when the oil film will exude from the cracks and stain the whitened surface.

A surer method of detection in large caliber guns is to draw a trained lad through the bore on a mat, when a close personal surface inspection can be made.

Dr. Giolitti's second letter, published last month, reiterates the belief that cleanliness of the steel is a controlling factor. It would appear that Dr. Giolitti's main contention is that a "really clean steel" should not be liable to flake when the forging is allowed to cool normally in air from the forging temperature. This involves a definition of "clean steel," but it is questionable if any cleaner acid open-hearth steel is produced, which after casting into 75-in. octagonal ingots, normally cooled, and forged, will give better physical properties than the average transverse official test results from both muzzle and breech ends of the gun forgings quoted in my original article — yet these forgings were flaked badly.

It will also be generally admitted that the cleanest steels it is possible to produce will, when cast into ingots of large cross-section and normally cooled, segregate over a considerable area in their upper half. Despite a 30% croppage from the ingot there still will be a central zone in the finished forging which will contain well-defined segregates.

Now if the main cause of flake is the presence of inclusions in the crystal boundaries, we agree with Dr. Giolitti he has been "very lucky" in never having found flakes in large gun forgings made from clean alloy steel, as it is impossible to produce large forgings without them in some portion of the longitudinal axial zone.

However, when an ingot is split down its longitudinal axis and one half forged into a round billet and allowed to cool normally, the flake defects do not follow the areas of excessive inclusions, but concentrate toward the axis of the forging itself, indicating that these ruptures occur in the most highly stressed area.

Now turn attention to the really dirty steels: If inclusions in the crystal boundaries were the primary cause of flake, would it not be reasonable to anticipate disaster when a massive forging of large cross-section known to be made of "dirty steel" is drastically quenched? The present writer has tested such forgings, both solid and hollow. Transverse specimens reveal the well-known woody fracture (both reedy and conchoidal) and yet on a thorough examination have proved to be perfectly free from ruptures of any description.

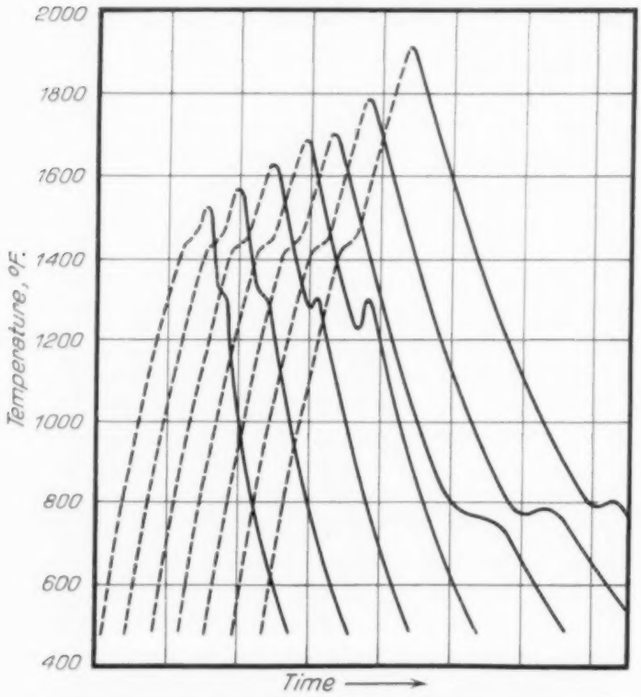
Mr. Margerum's statement that this flake defect has been known from early times in armor and armor piercing projectiles is fully confirmed by the writer's experience. In projectiles its presence spelt disaster and every precaution was taken to prevent it. On the other hand, in certain types of armor it was developed to its fullest extent back of the carburized face. The great advantage of this "laminated structure" was to produce exfoliation on impact of the projectile, to divert its path and prevent penetration.

Lastly, it is universally accepted that the Swedish steels are the best and cleanest produced. In this connection see the very excellent paper given by A. Hultgren on "Flakes and Hair Lines" before the British Iron & Steel Institute in 1925. In the discussion of that paper the present writer ventured the opinion that flakes were associated with inclusions, as in a number of cases they had been found to be coincident. Hultgren in his commentary expressed caution, as he had made numerous examinations of Swedish fine steels containing flake defects, and after a reinvestigation I found many flaked samples were of particularly clean steel. My later investigations have therefore fully confirmed Hultgren's contention.

Variations in Furnace Practice

For some years past it has been the belief of many that the origin of this disease dates back to the actual steel making process. Although disposed to agree with this assumption, there has been no definite proof so far as I know. Melts of steel have been made under the best controlled conditions known and graded as being immune from this trouble, but experimental blocks cut from the forgings during its processing and allowed to cool normally have been found to be far from acceptable. Every melt therefore should be regarded with suspicion and treated accordingly.

A Series of Cooling Curves of an Alloy Steel Showing How Maximum Temperature Is Responsible for Lowered Transformation, Into a Region Where the Metal Is Relatively Rigid



It is quite conceivable that any manufacturer having learned by costly experience the cause of this type of failure would with all subsequent melts take all precautions for the production of sound forgings. This probably explains the reason for the later success from certain furnaces, and not any chance influence of the steel making conditions.

As the presence of "chrome checks" has been mentioned in this correspondence and in the recent work by Eilender and Kiessler published in V.D.I. Zeitschrift in 1932, I would question it as a basic cause of this disease. Melts of 3% nickel steel, free of any chromium, made by the acid or basic open-hearth or basic electric furnace all have shown this undesirable defect to a marked degree. In fact, it has been the writer's experience that the tendency for these ruptures to form is less in the straight chromium or chrome-molybdenum steels than when these alloys are associated with nickel—quite a natural sequence, as the addition of nickel depresses the temperature of transformation.

This brings us to what, in the present writer's opinion, is the true cause of flakes. Flakes are due primarily to stress concentration and rupture of the brittle carbide constituents between the crystal boundaries.

The superimposed heating and cooling curves prepared by Harry Brearley many years ago and reproduced alongside will serve a useful purpose by showing very clearly the low temperature volume change when alloy steels are cooled from elevated temperatures. The steel at this low temperature offers great resistance to deformation and, being in the form of a large forging and consequently of a comparatively coarse grain structure, ruptures at points of stress concentration.

W. P. Benter, in his letter to METAL PROGRESS, published in May, writes that flakes usually form along the interstices of the dendrites. To this statement the present writer does not agree.

The mechanism of freezing of ingots carefully cast, and of a size suitable for forging or rolling into blooms, is progressive in its crystalline structure. The outer casing or shell first formed constitutes the small chill crystals; these for a short distance are followed by a growth of dendrites, and finally the greater part of the cross-sectional body of the ingot is composed of equi-axed crystals. As may be deduced from the location of flakes in large forgings, "flake fissures" form along the boundaries of these equi-axed crystals. (Perhaps these equi-axed crystal boundaries are sometimes misinterpreted as dendritic boundaries.)

I have before me at the moment a macrophotograph of a large disk made by upsetting a bloom for about 75% of its original length. The dendritic boundaries have been so distorted that they form well-contracted ellipses. This material is badly flaked throughout its central area and for at least half its diameter. Despite the tendency to weaken the dendritic boundaries by this heavy distortion in upsetting, no flake ruptures have taken place in these outer areas.

Some instances are on record where flakes have covered the greater part of the cross-sectional area of large billets. This, however, has been due largely to the ingot casting conditions and an extended period of high temperature soaking prior to rolling or forging.

Regarding the susceptibility of steel to flake: Although the writer agrees with Mr. Margerum that it is not desirable to strip ingots too hot and charge them immediately into the forge furnace or soaking pit, the fact must not be overlooked that some of the worst cases of flake the writer has seen, and evidently Mr. Margerum has had similar experience, have been in large ordnance

forgings where the ingots or blooms have been allowed to cool to room temperature for cold trepanning prior to forging. These are examples where mass action and uneven cooling have been responsible for the internal ruptures.

Prevention

As pointed out in my original paper in last November's issue, the best method of prevention is to make sure that the forging cools very slowly and equally through the split transformation. Work should be stopped at 1600° F. and a completed forging returned to a preheated annealing furnace, the temperature equalized and then allowed to cool slowly down to 500° F. in the sealed furnace, reheated to 1600 to 1650° F. to refine the grain, and again cooled in the furnace to room temperature. Although little if any dispersion of the inclusions in the crystalline boundaries takes place during such a "normal" heat treatment, the brittle carbides are broken up and diffused, removing all subsequent danger.

Once flakes are present in small number, Dr. Giolitti says they may be cured by proper heat treatment. My experience has been that the temperature necessary to effect this cure is approaching a forging heat, and therefore renders any finished or semi-finished parts unserviceable.

Any forging known to contain flakes will redevelop flakes after reforging, if still above 3 in. in cross-section and allowed to cool uncontrolled from a forging heat. These flakes, however, are not the original defects but a new crop which has developed after the final forging operation. The original ones, providing they were not exposed to any oxidizing influence during heating, would have welded perfectly and be undetectable under any known means of investigation.

Mr. Margerum, by his statement that these flake fissures do not weld entirely on reforging, differs not only with the large number of investigators who have published their results, but also with the many manufacturers and fabricators in this country and in Europe who have exploited all known methods of testing and examination and have proved without question that unexposed flakes, after suitable heating and working, will weld up perfectly. This matter was carefully stated in the recently published work on this subject by Eilender and Kiessler, just mentioned.

Agreeing with the above hypothesis are many facts known about forgings. The location of

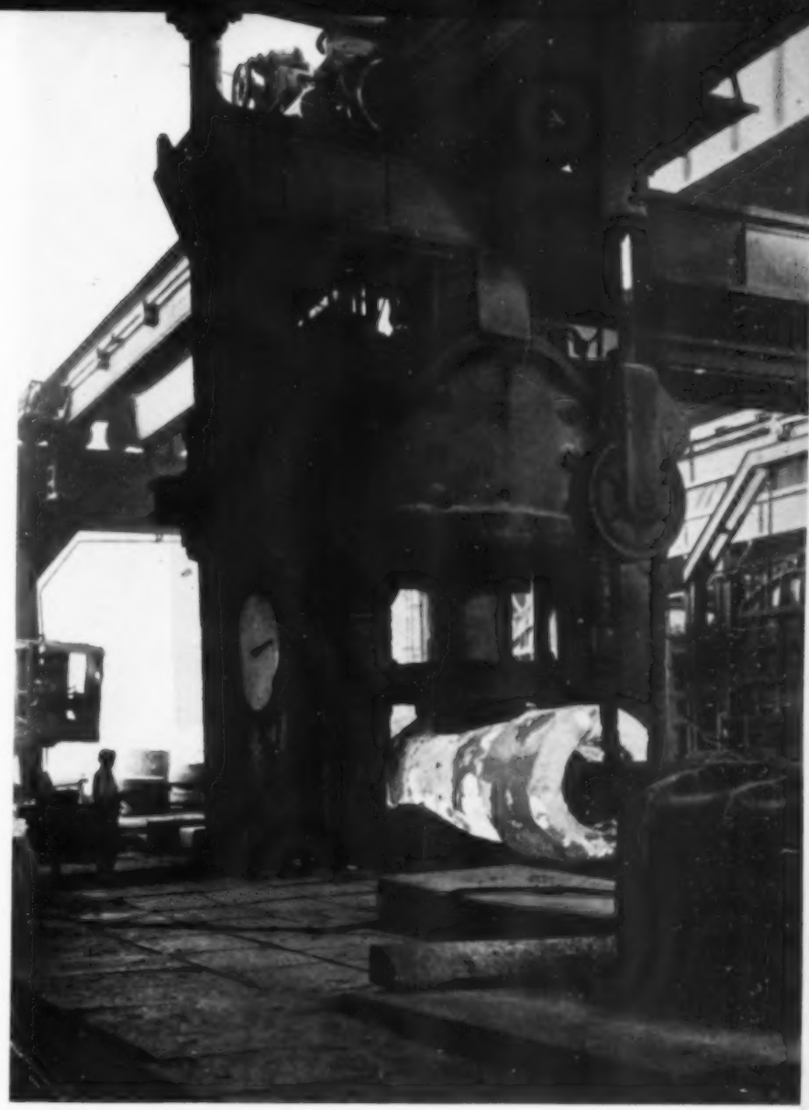


Photo Courtesy The Midvale Co.

flakes will largely depend on the method of forging the ingot and subsequent treatment of the finished forging. For instance, case *A*, the central portion of the ingot may first be forged to approximate size, followed by the reduction of the two ends. In case *B* the whole ingot may be cogged roughly to size and then finish-forged. In case *A* it requires little reasoning to realize that due to the greater rate of cooling of the greatly reduced cross-section of the first portion forged, this will be comparatively cool by the time the last end-portion of the ingot is finished, unless suitable precautions are taken. Under such conditions flakes will appear in the mid-length portion.

In case *B* where the ingot is reduced uniformly throughout its length, the temperature after forging equalized, and the forging slowly cooled, whatever troubles might develop would be of a uniform character, but under such controlled conditions a perfectly sound forging should be produced.

Rapid Work Does Not Mean Poor Work

Electrolytic copper wire, cold drawn "half-hard"; smoothed by hand and chemicals; final etching in concentrated HNO_3 and CrO_3. Magnification 1000 ×. Bausch & Lomb 5.5 mm. objective, 10 × eye piece, 60 cm. plate distance

By H. B. Pulsifer
Metallurgist
Ferry Cap & Set Screw Co.
Cleveland

SMOOTHING AND ETCHING

rapid metallographic methods

IT IS recorded of Dr. Sorby, the founder of the science of metallography, that he always finished his specimens by the simplest hand procedure, and that those who later used polishing wheels could not improve upon his results. But that is a story largely pertaining to a past century. More recently there have been great improvements in the construction of finishing wheels and the art of smoothing, so that now-a-days one might hesitate to affirm that hand finishing is superior to mechanical finishing.

It should be borne in mind, however, that improvements have also come in hand finishing. Perhaps it is more accurate to say that they are nothing much more than variations in well-established technique, but the results actually give new advantages to the older method. Three such modifications that may be mentioned here are:

1. By finishing on a moist pat or flat pile of abrasive, a suitable surface is easily made and maintained ready for photographing. The ever-so-slightly concave surface will give a print with a large, flat field — 8x10-in. prints such as the one on the left hand page are easily made at the usual magnifications.

2. By slightly etching the sample at intervals during its finishing on the abrasive pat the method becomes very rapid; it largely avoids covered or smeared-over scratches, and exposes unflowed metal ready for a final etching.

3. Such chemical smoothing, or finishing, is far quicker and more desirable than any mechanical operation. Whenever it can be used, only a further slight etching of the components after final polish is needed before photographing.

Let us now consider some of the actual operations required for these desirable results:

In the first place, the specimens should be large enough to hold easily in the fingers. A flattened shape is also desirable for maintaining the single smoothed facet. A broad flat will also compact the pat of abrasive, instead of cutting into it. In other words, the specimen should be cut or mounted so that it is surfaced on the largest face of a moderately thin mass. The resultant of the tipping moment is thus always well within the base when pushing it about on the file and the papers, or on the pat of carborundum or tripoli. There is no tendency to round the edges or produce a convex surface.

There is no moral or practical necessity for finishing the specimen to the very edges unless it is wished to examine conditions at the border. One will also not hesitate to disregard a few residual scratches if abundant and representative areas for photographing are clear of them. The argument that the particular spot needed for a photograph might be disfigured by a scratch contains its own refutal. Such a spot must be unrepresentative.

After the specimen is cut or mounted, the actual smoothing is done as follows: First, the specimen is *pushed* back and forth over a mill file, held flat on a bench or table top until the facet is completed. A minimum but effective pressure is readily sensed by the operator.

Next it is *pushed* in succession over a fine emery cloth and then a series of suitably graded grit papers laid on plate glass until it is finally smoothed on used 000 or 0000 paper. It should require only 100 or 200 rapid strokes on each paper if they are sharp and in the best sequence of grades. Not over one cloth and three papers are commonly required.

If the specimen is a steel or iron alloy, it is then slightly etched before proceeding. The next polishing is done on a moist pat of washed carborundum powder. This pat is nothing but a "mud pie" 1 or 2 sq.in. in area and ⅛ in. thick; for convenience it may be placed on a cloth-covered piece of ¾-in. board perhaps 6 in. square. The specimen may be given not over a hundred rapid passes on the well-compacted pad of damp and tacky carborundum powder. Pressure is light so the metal rides on the mass of abrasive — it does not dig through and touch the surface of the board. This sequence of slight etching and rubbing need not be repeated over three times for the carborundum; then the same procedure is followed on a pat of tripoli.

A final etching should then develop excellent characterization for photographing. The slightly concave surface should be substantially free of scratches, and give large, flat fields when photographed.

The materials used are least expensive. I have found that carborundum powder sold as No. 600 grit, which may be bought by the pound,

Progress of Smoothing Tobin Bronze Annealed Wire

After 100 rubs on three papers, a total of 300 half-strokes. Photo shows scratches at 250 ×

Granular surface at 250 × after 100 half-strokes on tripoli pat. Not etched

is highly suitable. The same is true of the tripoli which may be secured from any dealer in polishing and buffing equipment.

To prepare, both powders are repeatedly washed and finally settled to be stored as sludge in bottles. The pat is kept covered to avoid dust, and a few drops of water is all that is necessary to wet a surface layer of the "mud pie" properly for polishing operations.

Notes on Polishing

The file and the dry papers naturally produce a surface that has an external zone of flowed metal. However furrowed and scratched this surface may be, it is sheared and vitreous. The damp, heaped abrasives seemingly function best by impregnating their surfaces with a mat of black metal powder, which apparently aids in smoothing; the metal surface then becomes *granular* instead of vitreous.

With many non-ferrous alloys and the softer ferrous alloys one can omit the carborundum and use only the tripoli pat. It is also convenient to omit preliminary etching on many non-ferrous alloys that blacken the tripoli by simple rubbing.

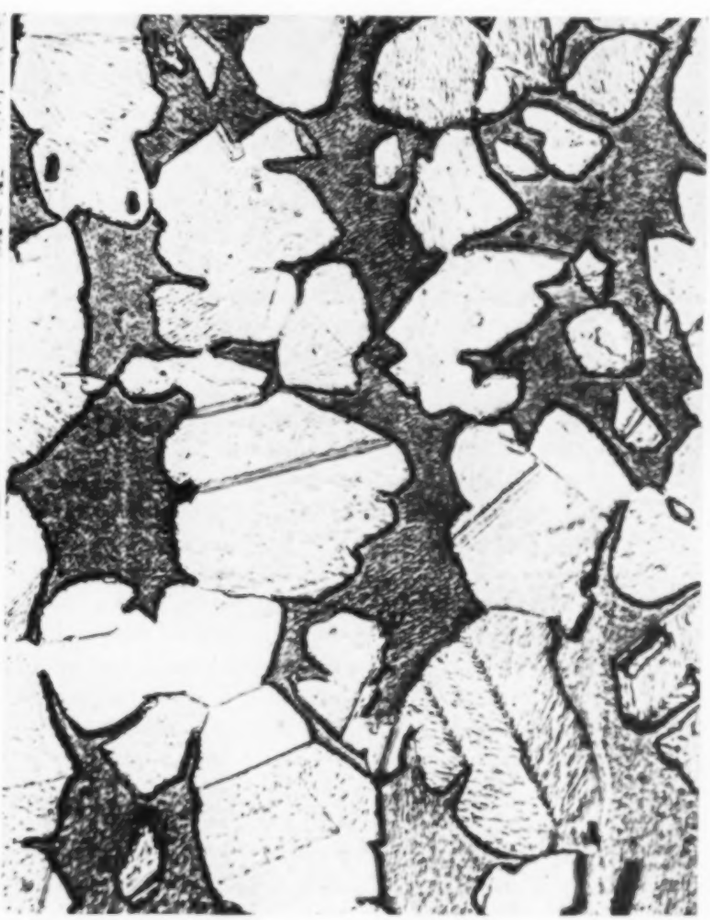
In all cases rubbing on hand boards is held to a minimum to avoid waviness, excessive relief, or scoring about holes and soft spots.

A slightly etched steel specimen that is rubbed on damp tripoli leaves a black smudge that shortly turns green (ferrous hydroxide) and then reddish (ferric hydroxide). With care, hundreds of specimens can be finished on the same heap of abrasive. Small renewals of the top layer are obviously advantageous, especially for the final rubbing.

Progress of Smoothing Tobin Bronze Annealed Wire

Surface chemically smoothed 1 sec. in concentrated HNO_3 plus CrO_3. 500 ×

Phases distinguished by dipping 2 sec. in nitric and acetic acid solution. 500 ×



Etching Technique

Materials range widely in their response to chemical finishing and etching. Crude metal is often grossly imperfect and its microstructure is seldom studied. Heavily cold worked metal and complicated alloys may be very difficult to portray clearly in all textures and components. Recrystallized solid solutions or annealed materials disclose their grain patterns, components, and fine structure most easily.

Those who are accustomed to the rapid etching of ferrous materials may be surprised with the splendid results of a slower etching in dilute picric acid in alcohol. Etching for 3 to 6 hr. in 0.5% picric acid, or overnight etching in a 0.1% solution may disclose a new perfection in structural delineation. In fact this is one way to outline ferrite sharply without over-etching the associated pearlite.

A few seconds agitation in concentrated nitric acid containing chromic anhydride will chemically finish many copper and nickel alloys almost magically. A further slight etching with more selective reagents, like nitric acid with a little water, or nitric acid in acetone will then put the components or fine structure in rich contrast. The specimen is always first rinsed in alcohol before washing and drying.

Concentrated hydrochloric acid containing chromic anhydride is suitable for finishing some of the more resistant alloys like duriron, silcromes and stainless alloys. It is also a remover of manganese stains after other etchings. A little 30% hydrogen peroxide in concentrated ammonia is a powerful finisher for many copper alloys.

Chemical finishing tends toward deep etching and abundant characterization. One is tempted to suspect that the faint etching of specimens, highly polished (mechanically), may have greatly retarded the progress of metal science. The fine structure within the unit usually termed a "grain" is the basis of all physical properties, yet it is still unknown to many metallurgists.

The above suggestions apply to all the ferrous alloys, copper and nickel alloys, and most common industrial materials. Often specimens can be made ready for photographing in from 2 to 5 min. A pat on a hand board has only to be moistened and it is ready to use — this is in great contrast with the work necessary to maintain polishing machines.

Tungsten and tantalum carbides presumably require finishing on diamond dust. Lead, tin, and the softer aluminum alloys are probably more efficiently surfaced by a smooth cut on a sturdy microtome.

Only a few instances of the results attainable by hand finishing can be submitted. In view of the speed with which such results can be accomplished and the simple equipment, it is probable that many metallographers will want to test the above conclusions derived from my own experience. Experiment and deduction will also lead them to doubt the truth of several statements made and remade in textbooks, such as:

That a small specimen can be finished quicker than a large one;

That a specimen should be rubbed until the scratches disappear;

That residual scratches necessarily impair the photographing of scratch-free areas;

That a specimen can be finished on a yielding fabric without crowning;

That a mathematically plane surface gives the best negative.

Incipient Tensile Rupture in Pearlite in Necked Tensile Specimen of 0.35% Carbon Steel. Polished and prepared for examination in 3 min. Etched over night in dilute picric acid (0.1%). Magnified 1000 diameters

By J. R. Townsend
Bell Telephone Laboratories
New York

relation of hardness of NON-FERROUS METALS to strength and workability

FOR several years studies of various methods of hardness testing in common use have been made in Bell Telephone Laboratories from the standpoint of their relation to the useful properties of cold rolled non-ferrous metals. The ease with which a hardness test may be applied and the fact that it is a non-destructive test in most cases, has rendered it a most practical gage of the quality of metals.

The ideal is this: To determine in terms of length, mass and time the penetrability of a metal by a penetrator, the test to be applied in such a way as to reduce all personal errors to a minimum and be of universal application to all metals. The result of our studies indicates that a penetration constant proposed by Meyer is the most scientific method thus far developed, even though it is not in commercial use at present.

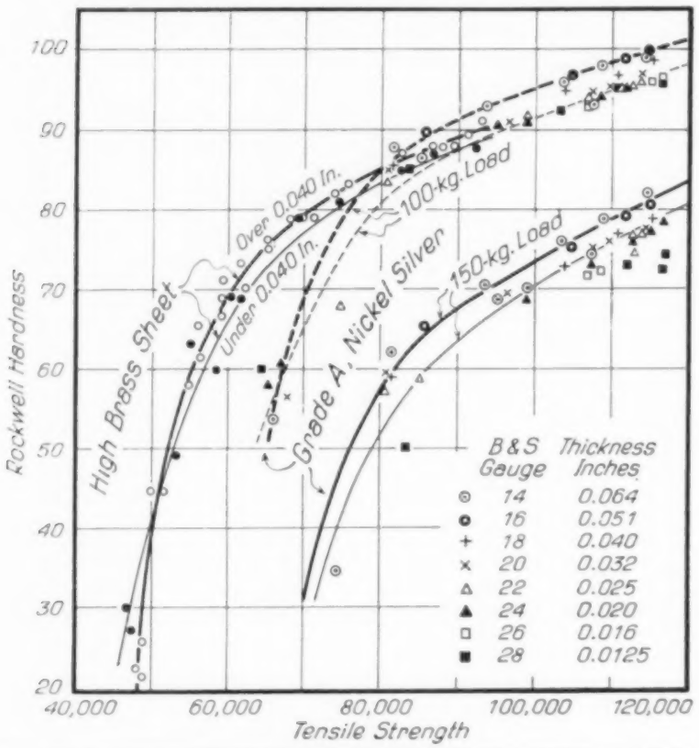
Work done prior to 1929 led to the selection of the Rockwell hardness tester as the simplest and most reliable commercial machine for non-ferrous metal sheet. The principal results were published by Messrs. Van Deusen, Shaw, Davis, Townsend, Straw and Munson in *Proceedings* of the American Society for Testing Materials, Vol. 27, part II, page 173 and Vol. 29, part II, pages 381 and 422. All the common methods of hardness testing (including the Vickers and the monotron) have since been compared with Meyer's analysis of the Brinell test, wherein the load to produce unit penetration of a ball into the metal is set forth as the most scientific method.

From a practical viewpoint it may be said that the hardness test (by penetration) is most useful in brass mill work to control or designate the heat treatment. Furthermore the tensile strength of cold worked non-ferrous metals bears a close relationship to the Rockwell hardness, or to the load required to produce unit penetration of a penetrator (Meyer's analysis, as given in *Zeitschrift* V.D.I., 1908). Our tests and comparisons, however, indicate that wear resistance, fatigue, toughness as revealed by reversed bend tests, 90° bending and forming tests, measure qualities of metals not revealed by hardness tests.

Hardness Tests

The Rockwell test has been fully described in the previous papers above noted, and is too well known to bear repetition. The upper lines of the first diagram show the results of the Rockwell hardness tests on a series of high brass sheets, rolled to various tempers, plotted against the respective tensile strengths. The method of carrying on these tests is described in Appendices I and II of the A.S.T.M. paper first mentioned. The Rockwell test shows such good correlation with

Rockwell Hardness Has Approximate Relationship to Tensile Strength of Non-Ferrous Sheet, Annealed or Cold Rolled. Hardness tests made with $\frac{1}{16}$-in. ball readings on B scale (red figures) under 100-kg. load (except for lower right curve)



tensile strength for cold worked metals that smooth curves may be drawn.

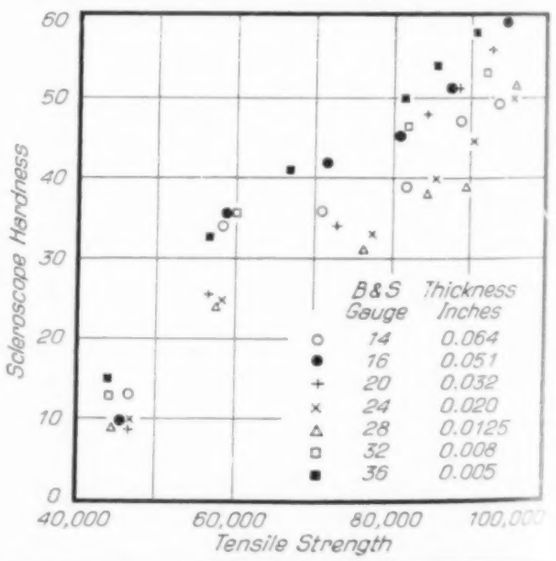
Higher loads giving greater penetration offer greater precision, provided the thickness of metal will permit. This led to the selection of a 150-kg. load with $\frac{1}{16}$-in. diameter penetrator for hard rolled nickel silver sheet, whereas for the softer brass a 100-kg. load is sufficient. This is brought out by the other curves on the above diagram.

Scleroscope — The Shore scleroscope test consists in dropping a hammer from a constant height which strikes the specimen and rebounds. The hammer falls in a glass tube which is divided into 140 divisions. The 140 divisions correspond to the maximum height of rebound of the hammer when testing hard steel. In our tests the universal diamond-pointed hammer was used. Results of scleroscope hardness test vs. tensile strength for a high brass rolling series are shown in the lower diagram on this page. It will be noted that the relationships are quite confused.

The Monotron test consists in forcing a ball penetrator, 2.5 mm. in diameter, 0.0018 in. into the specimen under test. The load in kilograms required to produce this indentation is read on a dial gage. This penetration was selected to make the scale usable for soft metals and for hardened steel without unduly loading the diamond penetrator when testing hard steels. A scale of 160 kg. is provided. In operation the load is applied through a lever by hand until the hand on the penetrator dial reads 9 whereupon the corresponding load is read on the load scale. The results of tests on sheet brass scatter about as much as those shown for the scleroscope.

The Vickers Tester consists essentially of a means of indenting the specimen with a diamond, a quadrilateral pyramid whose apex is forced into the specimen. An accurately measured load is applied and a small indentation is left in the specimen. The diagonal of the indentation is measured by a microscope in thousandths of millimeters. The angle formed by the diamond's opposing edges is 136°, which permits the determination of a hardness number in terms of a Brinell number. Vickers hardness vs. tensile strength for the high brass rolling series was plotted, and again the scatter was considerably too great.

Scleroscope Tests on a Series of High Brass Sheets Cold Rolled to Various Strengths. The results are too scattering for this hardness test to become a satisfactory basis of specifications. Tests on Monotron and Vickers penetrator also scatter in a similar manner



Meyer's Analysis

In a critical analysis of the Brinell test, Meyer suggested the use of the mean pressure that is supported by the metal, which was derived by dividing the load by the projected area of the ball indentation (rather than the spherical area of the ball indentation as used in figuring the Brinell numbers). It was shown that the pressure plotted against the diameter varied in a regular manner with the load. The equation of the resulting curve is $P = ad^n$, where a is equivalent to the resistance of the metal to penetration and, as shown by the curves on page 38, bears a constant relationship to tensile strength. The exponent n indicates the "work hardenability" of the metal. (The use of this exponent for indicating the quality of cold worked metals has not been completely explored, but it appears to have some interesting possibilities.)

An experimental type of Brinell machine is shown in the accompanying halftone. It was devised to force a ball penetrator under increasing load into a specimen and to measure the amount of penetration of the ball while under load. In other words, the amount of load required to produce a predetermined unit penetration may be measured.

The machine consists essentially of a $\frac{1}{16}$-in. diameter ball penetrator, a lever system through which the load is applied, and means of measuring the depth of penetration. Load is controlled by moving a jockey weight upon the principal lever while penetration is measured by an optimeter to a precision of 0.00001 in. The load required to produce a penetration of 0.01 in. (or 0.001 in. if desired) is determined, yielding the constant a directly.

Experimental Hardness Testing Machine for Measuring Depth of Penetration Under Load, as Suggested by Meyer's Analysis

This machine involves, then, a measurement of unit load to produce unit penetration. Inasmuch as the penetration is measured with the load on, the amount of the penetration includes both the elastic and the plastic or permanent deformation of the metal.

Instead of measuring the diameter of the penetration it has been found better to measure the penetration, since the penetrator throws up a rim of metal which interferes with an accurate determination of the diameter; furthermore, in the

Chemical Specifications of Materials Tested

Designation	Copper	Zinc	Lead	Iron	Tin	Others
Grade A, or high brass	64.5 to 67.5	Balance	0.3 max.	0.05 max.		
Grade B, or clock brass	61 to 64	Balance	1.25 to 2.0	0.06 max.		
Grade C brass	83 to 86	Balance	0.15 max.	0.05 max.		
Grade D brass	73 to 76	Balance	0.25 max.	0.05 max.		
Grade E brass	64 to 67	Balance	0.8 to 1.1	0.08 max.		
Grade G, or 72:28 brass	70.5 to 73.5	Balance	0.10 max.	0.05 max.		
80:20 (nominally)	80	20				
Electrolytic copper	99.88 min.					
Duronze (nominally)	Balance				2%	Si 1%
Everdur (nominally)	96					Si 3%, Mn 1%
Milloy	0.75 to 1.25	Balance				Mn 0.007 to 0.015
Monel metal (analysis)	28.26			1.47		Mn 1.16, Ni 68.65
Grade A nickel silver	70.5 to 73.5	Balance		0.35		Ni 16.5 to 19.5
Grade B nickel silver	53.5 to 56.5	25.5 to 28.5		0.35 max.		Ni 16.5 to 19.5
Grade A phosphor bronze	94.4 min.				3.8 to 4.8	P 0.05 to 0.35
Grade C phosphor bronze	91 min.			0.10 max.	7.5 to 8.5	P 0.05 to 0.25
Grade D phosphor bronze	90 min.		2.5 to 4.0		4.0 to 5.5	P 0.05 to 0.25

case of cold worked metals, there is more recovery in the direction transverse to the direction of rolling than parallel to it, and the indentation is quite definitely elliptical.

Correlation of Results

As noted at the outset, a large amount of work has been done on various cold rolled alloy sheets, and only a few representative data can be presented in this limited space to support the general conclusions. A table on page 37 gives the chemical specifications of materials which were studied.

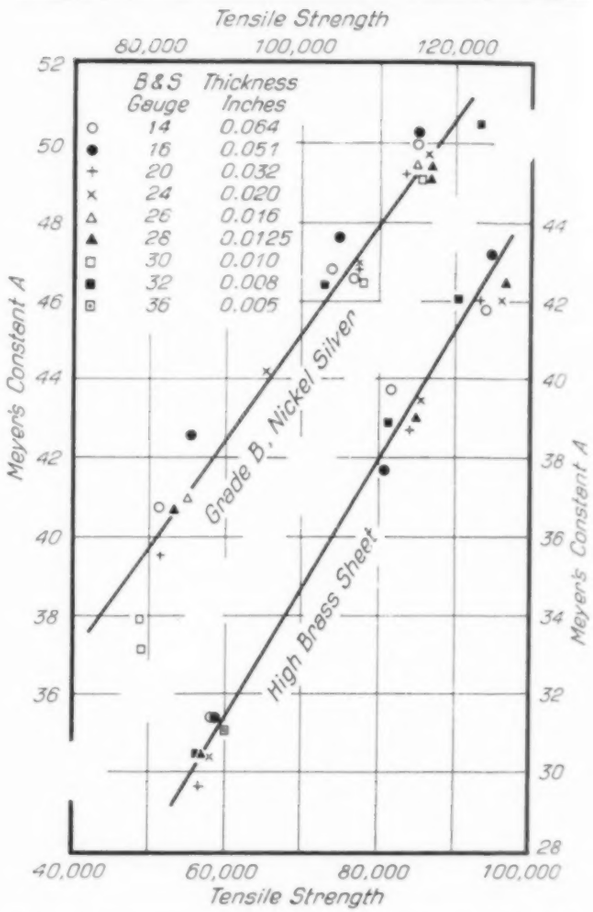
Taking all our results into consideration the Rockwell and Meyer's test methods alone appear to give results following a smooth curve when plotted against tensile strength. There is a difference in Rockwell results between metals less than 0.040 in. thick and metals 0.040 in. thick and thicker. As was previously pointed out in the A.S.T.M. papers, this appears to be a characteristic of the Rockwell tester.

The Monotron and Vickers hardness numbers bear no close relationship to tensile strength except for particular thicknesses. In other words, these tests are gravely affected by the thickness of the metal.

The Meyer's constant a is unaffected by thickness provided a suitable depth of penetration (namely, not more than $\frac{1}{3}$ the thickness of the metal) is employed. There should be no limit to the thinness of metal with which this test should be successful other than the difficulty of measuring extremely small penetrations accurately. With proper measuring equipment this test should be applicable to foils or sheet metals less than 0.005 in. thick.

Particular attention is called to the method of making an indentation test in this way. A ball penetrator of specified dimensions is forced into the specimen until a unit penetration is reached whereupon the load required to produce this penetration is taken as the hardness of the metal. Our definition of hardness then becomes "the load required to force a ball of unit dimensions to unit depth in the material under test." If a diamond ball is provided there is no reason why any material, metal or non-metal, should not be tested.

All methods of hardness testing have their particular field of usefulness. The Brinell test has become standard for heat treated steel parts. The scleroscope is useful as a quick check on relative hardness. The Monotron and the Vickers testers are new, and are finding a field of usefulness. The Rockwell tester remains a most flexible machine and capable of use with a variety of loads and penetrators. The Meyer method is unaffected by thickness of the specimen.



Meyer's Constant ("A", Pounds Required for $\frac{1}{16}$-In. Ball to Penetrate 0.001 In.) Has Straight-Line Relation With Tensile Strength of Non-Ferrous Sheet, Substantially Independent of Thickness and Fabrication History

Other Methods of Test

While hardness (and, inferentially, tensile strength) are very valuable properties for control and design purposes, there are many services which are not predictable from them. Some of these will now be considered.

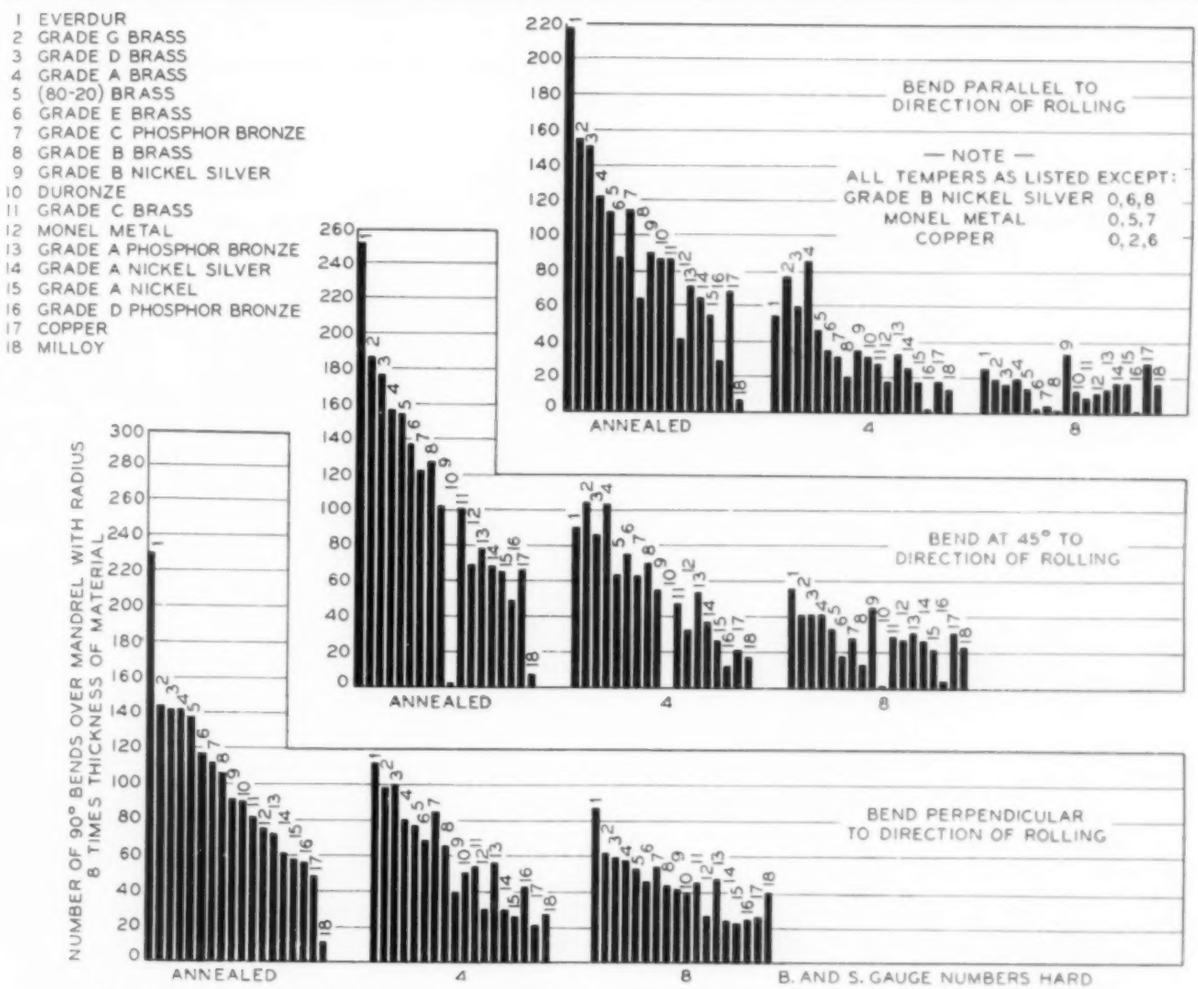
Reversed Bend Test — This test consists essentially of mounting strips of metal, ½ in. wide, between jaws having uniform radii at the top edges. The metal is then bent through reversed 90° bends until it breaks.

Since the number of bends plotted against the ratio of the thickness of the metal to the radii of the clamping blocks is a straight line when plotted on logarithmic paper, two sets of blocks of differing ratios may be selected, the tests run and data plotted, whereupon the number of bends to failure for any given ratio of thickness of metal to radius of blocks may be determined by interpolation. A ratio of 8 to 1 has proven to be most satisfactory, as set forth in the previous A.S.T.M. paper (1929), which described results on sheet brass with the grain direction 90° to direction of bending.

Subsequent results with other sheet metals and with the grain parallel and at 45° to the direction of bending have shown that this relationship does not hold strictly. Since in a majority of cases the relationship is linear, three pairs of mandrels with a ratio of 8 to 1 are used to determine the number of bends to failure.

The large diagram on this page summarizes reverse bend tests on eighteen metals and alloys, indicating how the result is affected by amount of cold work ("temper") and direction of testing in relation to direction of cold rolling. Brief comments on the results will be given below.

The 90° Forming Test was described before the American Institute of Mining & Metallurgical Engineers in 1931 by Messrs. Straw, Helfrick and Fishrupp. It consists in forming sheet metal, approximately ½ in. wide, on a punch press operating at the rate of approximately 148 strokes per min. A series of forming tools are used in the test, each of which has a definite radius of curva-


1 EVERDUR
2 GRADE G BRASS
3 GRADE D BRASS
4 GRADE A BRASS
5 (80-20) BRASS
6 GRADE E BRASS
7 GRADE C PHOSPHOR BRONZE
8 GRADE B BRASS
9 GRADE B NICKEL SILVER
10 DURONZE
11 GRADE C BRASS
12 MONEL METAL
13 GRADE A PHOSPHOR BRONZE
14 GRADE A NICKEL SILVER
15 GRADE A NICKEL
16 GRADE D PHOSPHOR BRONZE
17 COPPER
18 MILLOY
BEND PARALLEL TO DIRECTION OF ROLLING
— NOTE —
ALL TEMPERS AS LISTED EXCEPT:
GRADE B NICKEL SILVER 0,6,8
MONEL METAL 0,5,7
COPPER 0,2,6
BEND AT 45° TO DIRECTION OF ROLLING
BEND PERPENDICULAR TO DIRECTION OF ROLLING
NUMBER OF 90° BENDS OVER MANDREL WITH RADIUS 8 TIMES THICKNESS OF MATERIAL
ANNEALED
4
8
B. AND S. GAUGE NUMBERS HARD

For Many Uses and Fabrication Operations the Ability of an Alloy to Withstand Reverse Bending Is of Great Importance. This is not related to tensile strength, it varies with the temper and direction of rolling, and may be determined in a test outlined in the text

ture at the end. This causes the sheet metal to be formed to a 90° bend over the equivalent of a series of mandrels of various diameters.

The radius of the forming tool which first causes cracking of the metal's "fibers" is taken to be the smallest radius that the material may be successfully formed. Typical limiting radii of forming of various cold rolled sheet materials are given in the table on this page, based on data contained in the paper mentioned and also on subsequently collected data.

Erichsen Ductility Test has been described in detail in the first A.S.T.M. paper, wherein it was shown that this test was not sufficiently precise to be used alone as an inspection test for sheet non-ferrous metals. Thomas Dockray reaches the same conclusion as to sheet steel in his paper in METAL PROGRESS in October, 1931.

Endurance—The present author and C. H. Greenall presented a paper to the American Society for Testing Materials in 1929 wherein it was shown that the fatigue resistance of non-ferrous sheet metals increased only slightly with increase in tensile strength and hardness. More recent tests show also that the endurance limit varies more with direction of rolling than with increase in tensile strength.

Discussion and Conclusion

It is evident from these results that hardness testing alone is not sufficient to determine the useful properties of metal. For example, reference to the figure on page 39 shows that annealed everdur is superior to all the sheet metals tested from a reversed bend standpoint. Copper and milloy have greater resistance to bending in the harder tempers, while the other metals have decidedly less. In most instances the best direction for bending is 45° to direction of rolling; the exceptions are Grade D phosphor bronze, monel metal, duronze and milloy.

The effect of grain direction is not considered in hardness testing, and must be found from tensile, bend, or fatigue tests. The extraordinary resistance of annealed everdur to reversed bending was unsuspected from its tensile strength or hardness. The converse behavior of copper and milloy was equally unsuspected. Of particular interest also is the behavior of Grades B and E brasses, which, while they are commonly used for deep forming, are inferior to the other brasses.

Even while thus recognizing the fact that hardness tests do not tell everything, they are very useful and much would be gained in simplifying and rationalizing them by defining hardness in terms of penetration of a hard ball penetrator into the substance under test. This can be done in terms of length, mass and time. It is proposed, therefore, that penetration hardness be defined as the load required to produce unit penetration of unit penetrator in unit time, the penetration being measured under load.

Hardness tests made in this way (so as to determine the load required to produce unit penetration) bear close relationship with tensile strength in cold rolled non-ferrous metals, regardless of the thickness of the material. This relationship exists due to the fact that both tests measure the elastic plus the plastic resistance of the metal to deformation. Such hardness tests may therefore be compared with the tensile test, and since such a hardness test is easier and cheaper to make than the tensile test, it should achieve extensive use. If this is generally recognized, a universal simplified form of hardness testing should result.

Hardness testing, however, does not bear a close relationship to the bending, forming, fatigue, ductility and other useful properties of metals. It is necessary therefore to carry on such tests, since they will reveal striking properties not suspected from the results of hardness and tensile strength tests.

Limiting Radii [in 1/32 in.] for Forming Non-Ferrous Sheets 0.020 In. Thick

Material	Direction*	Temper in B & S Numbers Hard			
		2 ("½ hard")	4 ("Hard")	6 ("Extra hard")	8 ("Spring")
High Brass Sheet	90°	S	S	1	1
	45°	S	S	2	3
	Parallel	S	0.5		7
Clock Brass	90°		S		2
	45°		1.5		5
	Parallel		3		8
Nickel Silver "A"	90°		3	4	
	45°		2	4	
	Parallel		3	4	
Nickel Silver "B"	90°	S	1	1.5	
	45°	S	1	3	
	Parallel	S	3	5	
Phosphor Bronze "A"	90°	S	S		1
	45°	S	1		6
	Parallel	S	2		
Phosphor Bronze "C"	90°	S	2		3
	45°	S	8		
	Parallel	S			
Everdur	90°	S†	1		
	45°	S†	1		
	Parallel	S†	2		
Milloy	90°	1.5†	S		
	45°	2.5†	S		4
	Parallel	4†	1		6

* Direction of bend to direction of rolling † Data for annealed metal
S = Sharp bend, less than 1/64 in. radius

By E. W. Skinner
Associate Professor
of Basic Dental Technology
Western Reserve University
Cleveland

DENTAL METALS

and their manipulation

DENTISTS, as well as other members of the medical profession, use the finest steels for tools and instruments. A physician's repairs, however, are usually made with flesh and bone; the dentist as frequently inserts a bit of metal and it is expected to last a lifetime without discoloration or deterioration. Requirements for such metal are obviously quite specialized and very rigid; superior alloys of the noble metals have recently been developed by physical chemists by means of advanced metallurgical theory —hence the reason for an article in such a journal as METAL PROGRESS.

Gold, in the pure state, was one of the first metals to be used for fillings. "Cohesive" gold foil welds under pressure at room temperature. It is usually supplied to the dentist after corrugating or crimping by heating it between sheets of paper in the absence of air. Surface gases and the slightest strain hardening of the foil prevent its condensation or welding. For this reason, the foil must be thoroughly annealed just before use. Piece after piece is condensed into the cavity with blows from a small mallet, and a blunt pointed instrument called a "gold plugger." The cavity is gradually built up in this manner, until filled in excess. If the procedure has been successfully done, a hard mass of welded gold results.

Its physical properties are excellent. Due to the cold working, the metal increases in hardness to a Brinell number of about 60, whereas that of pure gold is 27. In malleting the foil, the cavity walls are distended slightly, and the filling is retained in a wedge-like grip effectually preventing ingress of foreign material.

Gold is, of course, one of the most noble metals and is unaffected by saliva and food and fruit juices.

As a matter of fact, gold alloys are now more extensively used, and have been somewhat standardized as to their physical properties as the result of work done by the research group of the American Dental Association, working at the Bureau of Standards. Manufacturers should also be commended for their wholehearted cooperation, and their honest attempts to improve their products.

The compositions of these alloys may vary from the simple binary alloys of gold and copper, to alloys containing six elements. The usual constituents of a casting gold for crown and bridge work are, for example, gold, platinum, palladium, silver, and copper.

Zinc and tin are found only in casting alloys, to lower the melting point. They are rather inadvisable because they are likely to volatilize if carelessly cast or they may impair the nobility of the alloy. While corrosion resistance has not been studied as much as it should, it is estimated that the alloy should contain at least 50 atomic per cent of noble metals.

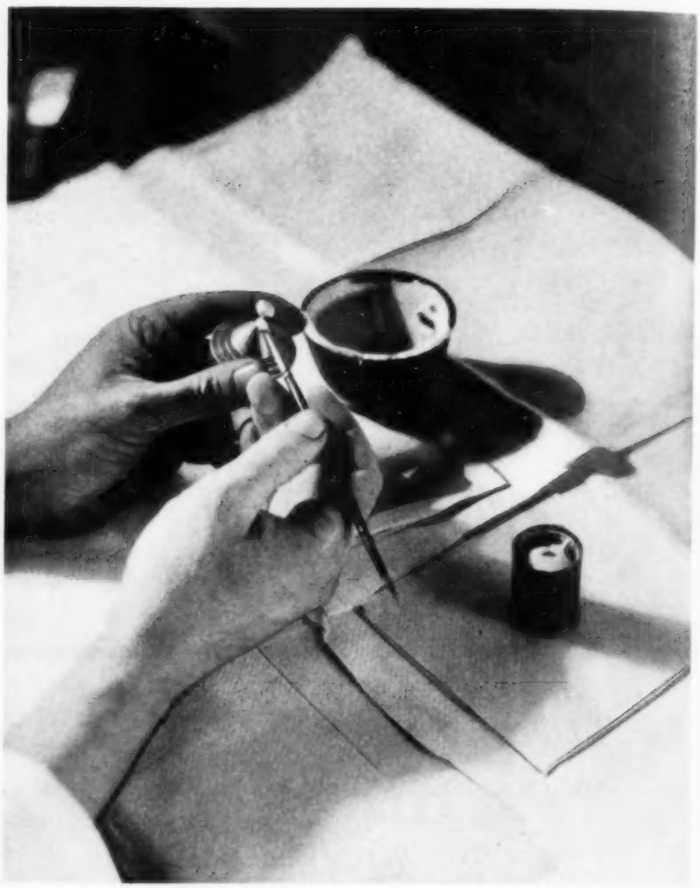
In the wrought form the alloy should contain

at least 75% of the gold and platinum group metals. Plates are used for swaging artificial dentures, and wire is used as clasps and orthodontic (tooth straightening) appliances. Such alloys in the oven cooled condition should have at least 150,000 psi. ultimate tensile strength, 125,000 psi. yield, and 4% elongation in 2 in. (or somewhat less ultimate and 15% min. elongation when quenched).

Gold Inlays

The casting alloys are more extensively used, as in inlays, bridges, crowns, and dentures (plates). Their physical properties may best be comprehended by noting the requirements set up by the Dental Group at the Bureau of Standards as shown in the table on page 44. The dentist has considerable latitude of choice, the criterion of selection being the amount of stress which the structure must stand and the amount of marginal burnishing necessary. The tensile strength of these alloys may run as high as 115,000 psi.

Rather simple equipment is used for making dental castings, yet high accuracy is required. Remarkable developments in standardized materials and casting procedure have occurred within the last few years.



A Wax Mold Is Placed on a Small Sprue, Painted With "Investment" or Molding Material, and Thrust Into a Small Brass Ring Full of the Latter. When the mold is set, the sprue is removed and wax melted out

There are two principal variables which must be taken into consideration: (*a*) Shrinkage of the alloy from molten state to room temperature, a constant and generally accepted as 1¼%, and (*b*), shrinkage of the pattern, or impression, from mouth to room temperature.

Pattern shrinkage depends largely upon the temperature of the room. There are in general two methods of obtaining a pattern: "direct" and "indirect." The direct method consists of forcing a wax into the prepared cavity in the mouth, so that it completely fills it, and the outer surface then carved exactly. The wax pattern, thus prepared, is removed from the mouth, and in so doing it contracts or expands. The magnitude of this change in volume depends upon the temperature gradient between mouth and room temperature.

These waxes show a surprising thermal expansion, which is by no means constant over the temperature range. A good one becomes soft at 104° F., hardens at 99° F., and shows an average thermal contraction of 0.4% when cooling to 68° F. Adding this contraction to that of the gold, a total compensation of 1.65% must be made for the structure to fit the tooth at mouth temperature, the thermal expansion of the gold alloy from room to mouth temperature being too small for consideration.

A small wire, or sprue, now is fastened to the pattern at a convenient point, and its other end fastened to a conical crucible-former, as shown in the first halftone. The mold is formed by an "investment," usually consisting of moistened 25% plaster of paris and 75% quartz (the allotropic form, cristobalite, being preferred). Before this material sets, the wax pattern is painted with it, carefully, so as not to entrap air. The remainder of the investment is poured into an

asbestos-lined casting ring, which is simply a piece of 1-in. brass tubing about 1½ in. long. The painted pattern is then inserted into this tube, pushed down until one end of the ring is sealed by the crucible-former. After the investment has reached its final set, the crucible-former and the sprue are drawn out. The ring is then placed in an electric oven, which melts the wax, leaving a mold which should be an accurate reproduction of the finished restoration.

The principal means of compensation for the shrinkages mentioned is by expanding the mold to a red heat. For example, investment containing 75% cristobalite expands 1.35% from room temperature to 1300° F., the allotropic inversion of quartz being taken advantage of. This expansion, together with the change in dimension during setting of the plaster of paris seems to furnish ample compensation.

Casting Technique

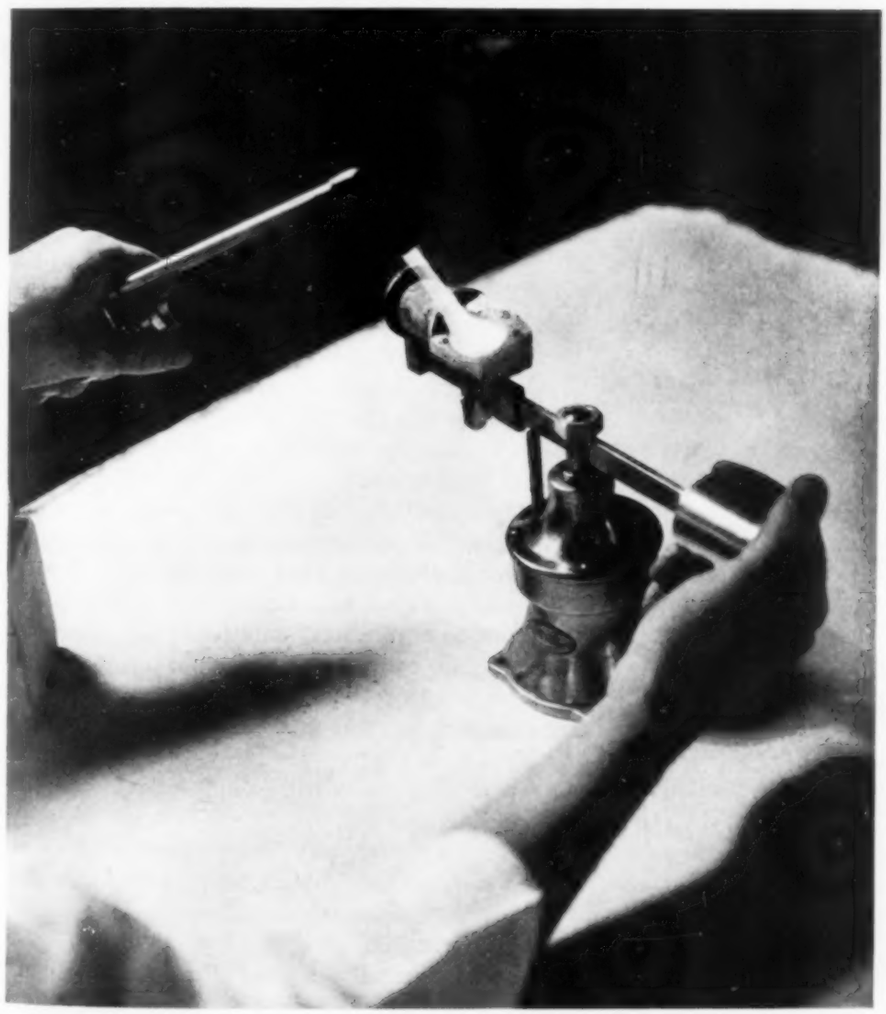
The temperature of the mold is judged by its red color, which is sufficiently accurate. The gold alloy is cast at this temperature.

A commonly used casting machine uses centrifugal force. The casting temperature is judged by the color and fluidity; the source of heat is usually a gas-air blow torch. As soon as the gold is fluid, it is fluxed, a coiled spring released, and the counterweighted arm whirls rapidly, throwing the gold into the mold by centrifugal force.

As soon as the gold ceases to glow, the ring and casting are quenched in water. The casting is freed from investment, pickled, contoured and polished, ready to be cemented into the cavity.

Castings from as small as a pinhead, up to as large as base plates for artificial teeth, may be made by essentially these methods with an accuracy of 0.1% or less.

Many of these gold alloys may be heat treated. Quenching in water leaves it in a soft, ductile condition. The alloy may then be hardened either by cooling through a given temperature range (called the "oven-cooled" process) or by aging or soaking the alloy at a specified temperature. The hardening process increases all the tensile properties of the alloy except ductility, which may be decreased even to brittleness. The strength and hardness may sometimes be doubled from the softened condition. The correct hardening treatment is specified by the manufacturer. The aging process seems to be superior, in that it



Hot Mold Is Attached to Refractory Cup Wherein Gold Is Melted. Release of spring whirls arm rapidly, driving molten metal into mold by centrifugal force

Requirements for Dental Inlays
Gold Colored Casting Alloys in Softened State

	Type A	Type B	Type C
Gold and platinum group metals (min.)	83%	78%	78%
Silver (range)	3 to 12%	0 to 15%	0 to 15%
Brinell hardness (range)	40 to 75	70 to 100	90 to 140
Yield (min.)		22,000 psi.	27,000 psi.
Elongation in 2 in. (min.)	18%	12%	12%
Fusion point (min.)	1725°F.	1650°F.	1650°F.

gives higher strength with less reduction in ductility than does the "oven-cooled" method for the same alloy.

The theory explaining these changes needs not be stated here. Age hardening is a phenomenon well known to metallurgists, and they will not be surprised to find that gold alloys are hardened by the same methods and mechanism as aluminum alloys. Gold-copper compounds are precipitated from solid solution, and obviously copper becomes a very important though minor constituent in the alloys.

Silver Amalgams

The dental amalgam carries with it the most colorful history. Although a correctly placed amalgam restoration is now second only to gold foil and inlays in permanency, it has weathered through stormy times to reach its excellence.

It was first used in 1826 as a "silver paste," a pure silver amalgam. Later copper was introduced from the use of coin silver. Unfortunately, the material fell into the hands of charlatans, who left in their wake a miserable trail of disease and misery, all due to the amalgam filling.

In 1845, the American Society of Dental Surgeons passed a resolution that any dentist who refused to abstain from the use of amalgam would be expelled from the Society. This move was followed by the famous "amalgam war" which split the profession into two factions.

The profession is greatly indebted to Dr. G. V. Black, the Sir Isaac Newton of dentistry, for finally straightening out the matter. His work was fundamental, and can be challenged only in a few minor points. He found (verifying the findings of previous workers in this respect) that pure silver amalgams expanded in size during the crystallization or setting period. He ingeniously balanced this change by another in tin in an alloy containing 72.5% silver and 27.5% tin. He also found that an alloy of 67.5% silver, 5% copper, and 27.5% tin was superior. Present specifications of the American Dental Association are 65% silver (min.), 25% tin (min.), 6% copper (max.), and 2% zinc (max.).

After the ingot has been prepared, it is shaved into filings, and then screened. The size of the particle affects the rate of amalgamation with mercury and the physical properties of the finished amalgam.

The filings are then aged or annealed by heat. This step is a very important one, as an alloy of correct composition may shrink while setting if the aging process is too prolonged. Conversely, if it is annealed insufficiently, it will expand unduly during set, even rupturing the tooth.

Even though an alloy has been properly manufactured, the amalgam may be ruined by incorrect manipulation by the dentist. The trituration with mercury must be accurately timed and standardized as to pressure of the pestle, and rate of trituration. Trituration is carried out first with a mortar and pestle until the mercury is absorbed by the filings; then the mass is mulled with the thumb in the palm of the hand until it is smooth and plastic. Over-trituration causes the amalgam to contract while setting, whereas under-trituration may cause abnormal expansion during this period.

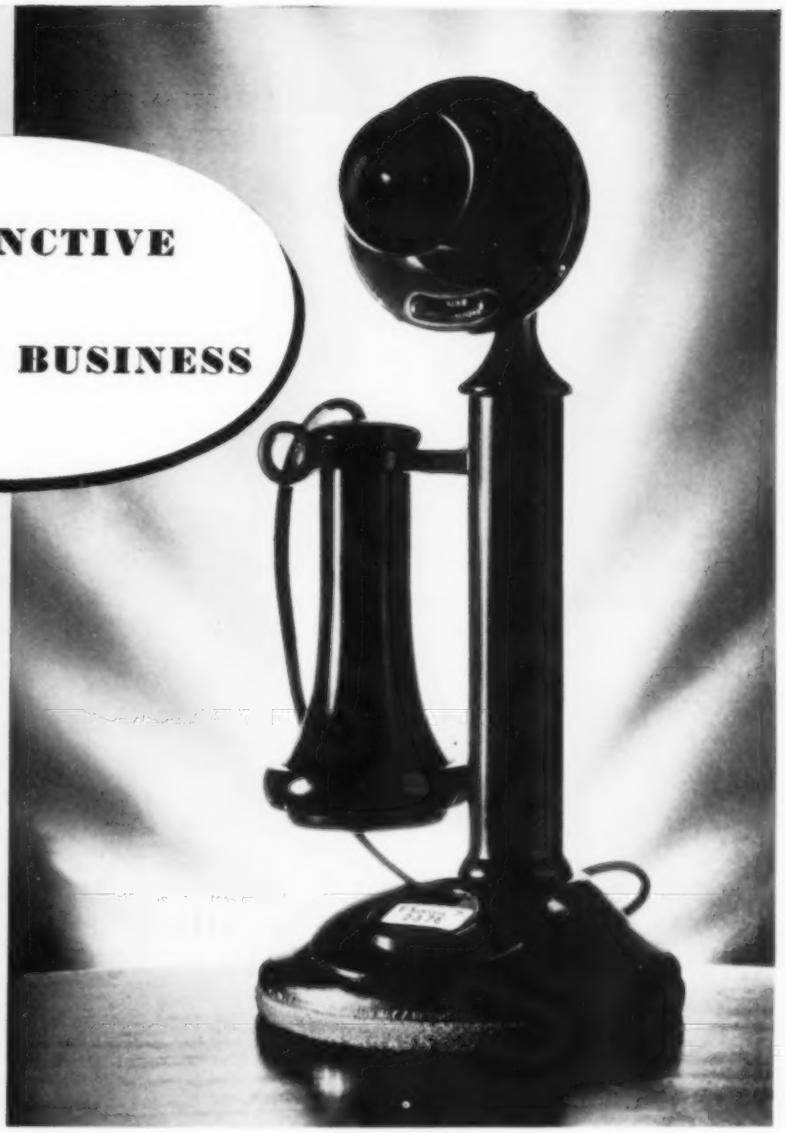
It is then condensed into the cavity with a special plugger, bit by bit. The excess mercury is expressed to the surface and discarded as the operation proceeds. The filling is finally contoured, and the patient dismissed for at least 24 hr., when the filling is polished.

To the author's knowledge, the constitution of these alloys has not been definitely determined. Even the constitution of the original filings is somewhat in dispute. Available thermal diagrams indicate an intermetallic compound Ag_3Sn, and if it is assumed that copper, silver and zinc are largely interchangeable, the quaternary alloy is probably made up of intermetallic compounds and a solid solution. The amalgam is even more complex — a mixture of intermetallic compounds, solid solutions, and eutectics. The silver-mercury compound has the formula Ag_3Hg_4, and copper probably gives a similar formula, while authorities differ as to the tin-mercury compound.

There are four physical properties of amalgam which are of importance: Setting changes, flow, ultimate compressive strength, and resistance to corrosion.

It is generally agreed that an amalgam should expand while setting, due to the differential thermal expansion *(Continued on p. 58)*

A DISTINCTIVE AMERICAN BUSINESS



The Bell Telephone System is operated in the interest of the public

THE Bell System is a widely owned organization operating a public service under federal and state regulation.

Its threefold purpose is to give the public the best telephone service at the lowest possible cost, give steady work at fair wages to its hundreds of thousands of employees and pay a reasonable return to the men and women who have invested in it.

The constant endeavor of the management is to deal equitably and honorably with each of these groups. There is no reason to do otherwise. There are 675,000 people who own the stock of the parent company—American Telephone and Telegraph. They are the owners of its nation-wide property. They are your neighbors. They live in every state of the Union and their average holding is twenty-seven shares. No individual or organization owns as much as one per cent of the stock.

In the truest sense, the Bell System is a business democracy—born in America, brought to its present stature by American enterprise, financed and operated by and for the people of America.

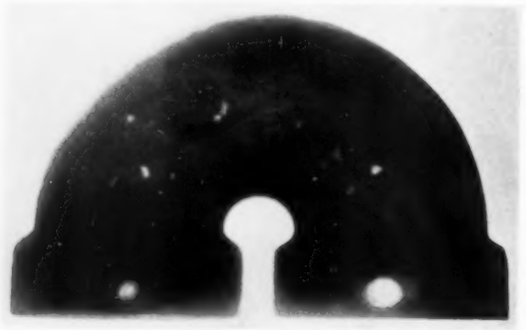
BELL TELEPHONE SYSTEM

"Checked and Doublechecked"

BUT

"The EYES Do NOT Have It"

PHOTOGRAPH *of Corrosion-Resistant Casting*



RADIOGRAPH *of* SAME *Casting*

The Human Eye is Good. . . . .

The Camera Lens is better, but

The X-Ray Tube Surpasses Both

Because it reveals the presence of *Defects*, such as shown above, which *Ordinary Inspection Methods* would approve as "Satisfactory."

●

THE ELECTRO ALLOYS CO.

ELYRIA, OHIO

"Quality Castings Since 1919"

Thermalloy

X-RAYED CASTINGS FOR HEAT CORROSION ABRASION

ARTICLES WORTH READING

General Articles

Characteristics Common to Carbon and Alloy Steels, Edgar C. Bain, Paper for American Iron & Steel Institute, Iron Age, May 31, p. 29A.

Titanium Alloys in the Automotive Industry, G. F. Comstock, Machinery, June, p. 609 . . . . Steel for Heat Treating and Forging, J. H. Hruska, Heat Treating & Forging, June, p. 275.

Economic Advances Due to Metallurgy, S. L. Hoyt, Metals & Alloys, June, p. 113 . . . . The Development of Alloy Steels, Harold Carpenter, Chemical Age, July 7, Metallurgical Section, p. 3.

Internal Stresses (A Series), C. S. Barrett, Metals & Alloys, June, p. 131 . . . . Elastic Strength, J. B. Kommers, Engineering, June 22, p. 695 . . . . Temperature and Its Measurement, E. O. Mattocks, Industrial Gas, July, p. 7.

Rejection Limits in Specifications, H. F. Dodge, Paper for American Society for Testing Materials.

Iron & Steel Melting

Design of Blast Furnace Lines, Jindrich Sarek, Paper for British Iron & Steel Institute . . . . Welding to Modernize a Blast Furnace, Boiler Maker & Plate Fabricator, June, p. 152.

Open-Hearth Production Problems, Iron Age, July 5, p. 36 . . . . Making Open-Hearth Steel With Natural Gas, H. J. Williams, Industrial Gas, July, p. 19 . . . . Sulphur in Open-Hearth Furnace Gases, E. Maurer, Paper for British Iron & Steel Institute . . . . City Gas for the Steel Industry, H. A. Fells, Gas World, June 16, p. 8 . . . . Effect of Fluorspar on Basic Slags, Lenher Schwerin, Metals & Alloys, June, p. 118.

Statistical Solution of Metallurgical Problems, W. C. Chancellor, Paper for American Society for Testing Materials.

Ingot Structures, L. Northcott, Paper for British Iron & Steel Institute . . . . Composite Steels Made by Inserts in Ingot Molds, M. R. Trembour, Iron Age, June 28, p. 28 . . . . Ingots for Forgings, J. H. Hruska, Heat Treating & Forging, May, p. 219.

Effect of Added Phosphorus on Low Carbon Steel, Report of Research Committee to American Society for Testing Materials.

Producing High Speed Steel in the Coreless Induction Furnace (A Series), Peter Bardenheuer, Steel, June 25.

Working of Steel

Steel for Deep Drawing, A. R. Page, Iron & Steel Industry & British Foundryman, July, p. 322.

Merchant, Strip, and Skelp Mill, Iron & Coal Trades Review, June 15, p. 963 . . . . Manufacture of Full-Finished Steel Sheets, E. R. Mart, Engineering, June 15, p. 689 . . . . Testing Hardness of Thin Steel Sheets, R. L. Kenyon, Paper for American Society for Testing Materials . . . . Testing Sheets for Blue Brittleness and Aging, R. L. Kenyon, Paper for American Society for Testing Materials.

Progress in Tube Rolling Mill Construction, Iron & Coal Trades Review, June 29, p. 1049 . . . . Microstructure of Cold Drawn Steel Tubes, E. P. Polushkin, Transactions, American Society for Metals, July, p. 635 . . . . The Bending of Thin Tubes, Machinery (British), June 14, p. 307.

Cold Drawn Steel for Special Sections, Product Engineering, July, p. 257 . . . . Properties of Cold Headed Bolts, C. L. Harvey, Transactions, American Society for Metals, July, p. 657.

• YOUR 6 REASONS

FOR ATTENDING THE SIXTEENTH ANNUAL

National Metal Congress and Exposition

1. To hear reports of the latest metallurgical progress read and discussed by outstanding investigators;
2. To see the greatest display since 1929 of equipment and materials — some of them you will see for the first time; nearly everything has been improved since you last saw it;
3. To visit interesting manufacturing plants and go through some of the finest research laboratories in the world;
4. To profit from the "University Short Course in Tool Steels" offered free to members of the A.S.M.;
5. To renew old friendships and make new ones at the year's largest gathering of progressive men in the world of metals;

IN GENERAL

6. To fit yourself for 1935 . . . a year of keen competition for both men and products.

A.S.Members: You will soon receive railroad certificates entitling you to a round trip to the Congress and Exposition for only one and one-third fares.

National Metal Congress and Exposition

American Institute of Mining and Metallurgical Engineers — Institute of Metals; Iron and Steel Division
American Society of Mechanical Engineers — Iron and Steel Division
American Society for Metals Wire Association
American Welding Society

New York City, October 1-5, 1934

A.S.M. Headquarters
Hotel Pennsylvania

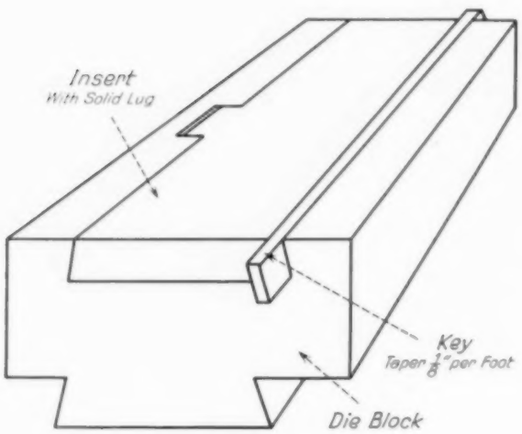
Exposition at Port
Authority Building

SKF 711
ALLOY TOOL STEEL

for

FORGING INSERTS

in . . . HAMMER
FORGING MACHINE } Dies
FORGING PRESS



Method of Fastening Insert

★ ★ ★ ★ ★ ★ ★

OTHER APPLICATIONS

DIECASTING DIES
SHEAR BLADES
PIERCING PUNCHES

●

SKF STEELS, Inc.

40 EAST 34th ST., NEW YORK, N. Y.

1242 W. WASHINGTON BLVD.
CHICAGO, ILLINOIS

330 NEW PARK AVENUE
HARTFORD, CONN.

ARTICLES WORTH READING

Iron & Steel Foundry

Effect of Non-Metallic Nuclei Upon the Graphitization in Cast Iron, Foundry Trade Journal, May 24, p. 335 . . . . Anneals Malleable in Small Furnace, L. J. Wise, Foundry, July, p. 21.

High Test, Heat Treated Alloy Cast Iron, E. F. Lake, Heat Treating & Forging, May, p. 233 . . . . Alloys in the Iron Foundry, J. Roxburgh, Foundry Trade Journal, May 24, p. 329 . . . . Addition of Molybdenum to Cast Iron, Foundry Trade Journal, May 17, p. 317 . . . . Chrome-Molybdenum Cast Iron at Mine Plant Foundries, R. H. Cromwell, Engineering & Mining Journal, June, p. 256 . . . . Molybdenum Cast Iron, C. M. Loeb, Jr., Steel, July 2, p. 26 . . . . High Duty Cast Iron in Textile Machinery, A. Roeder, Foundry Trade Journal, July 5, p. 3 . . . . Refined Cast Irons & Their Uses, W. West, Iron & Steel Industry & British Foundryman, July, p. 333.

Duplexing Malleable Cast Iron, Charles Morrison, Foundry, June, p. 25.

Tropenas Process for Steel Castings, J. E. Mercer, Foundry Trade Journal, May 31, p. 343 . . . . Steel Castings for Boulder Dam, Pat Dwyer, Foundry, June, p. 14 . . . . Pulverized Fuel Melting Furnace, Mechanical World, June 15, p. 573 . . . . Tests for Air Furnace Bung Bricks, Steel, June 18, p. 36.

Graphite Formation and Structure in Cast Iron, Heinrich Nipper, Foundry Trade Journal, July 5, p. 7 . . . . Metallurgy of the Cast Iron Piston Ring, P. S. Lane, Baltimore Engineer, June, p. 10 . . . . Porosity and Strength of Cast Iron, Foundry Trade Journal, June 28, p. 407 . . . . Car Underframes of Cast Steel, T. W. Lippert, Iron Age, July 12, p. 10.

Non-Ferrous Metals

Oil-Fired Rotary Melting Furnace, Mechanical World, June 22, p. 595 . . . . Pulverized Fuel for Metallurgical Work, Metallurgia, June, p. 41 . . . . Classification, Properties and Utilization of Non-Ferrous Scrap Metals, Metallurgia, June, p. 47.

Effect of Aluminum in Zinc-Base Die Castings, E. A. Anderson, Report to American Society for Testing Materials . . . . Protection and Decoration of Aluminum, S. Wernick, Industrial Chemist, June, p. 231 . . . . Pistons — Cast Iron Vs. Aluminum, Bus Transportation, June, p. 203 . . . . Arc Welding Aluminum, A. F. Davis, American Machinist, June 20, p. 438.

Developments in Main and Connecting Rod Bearings, S. W. Sparrow, S. A. E. Journal, July, p. 229 . . . . Laminated, Sheet Bronze, Graphited Bearings, C. H. Leis, Product Engineering, July, p. 263.

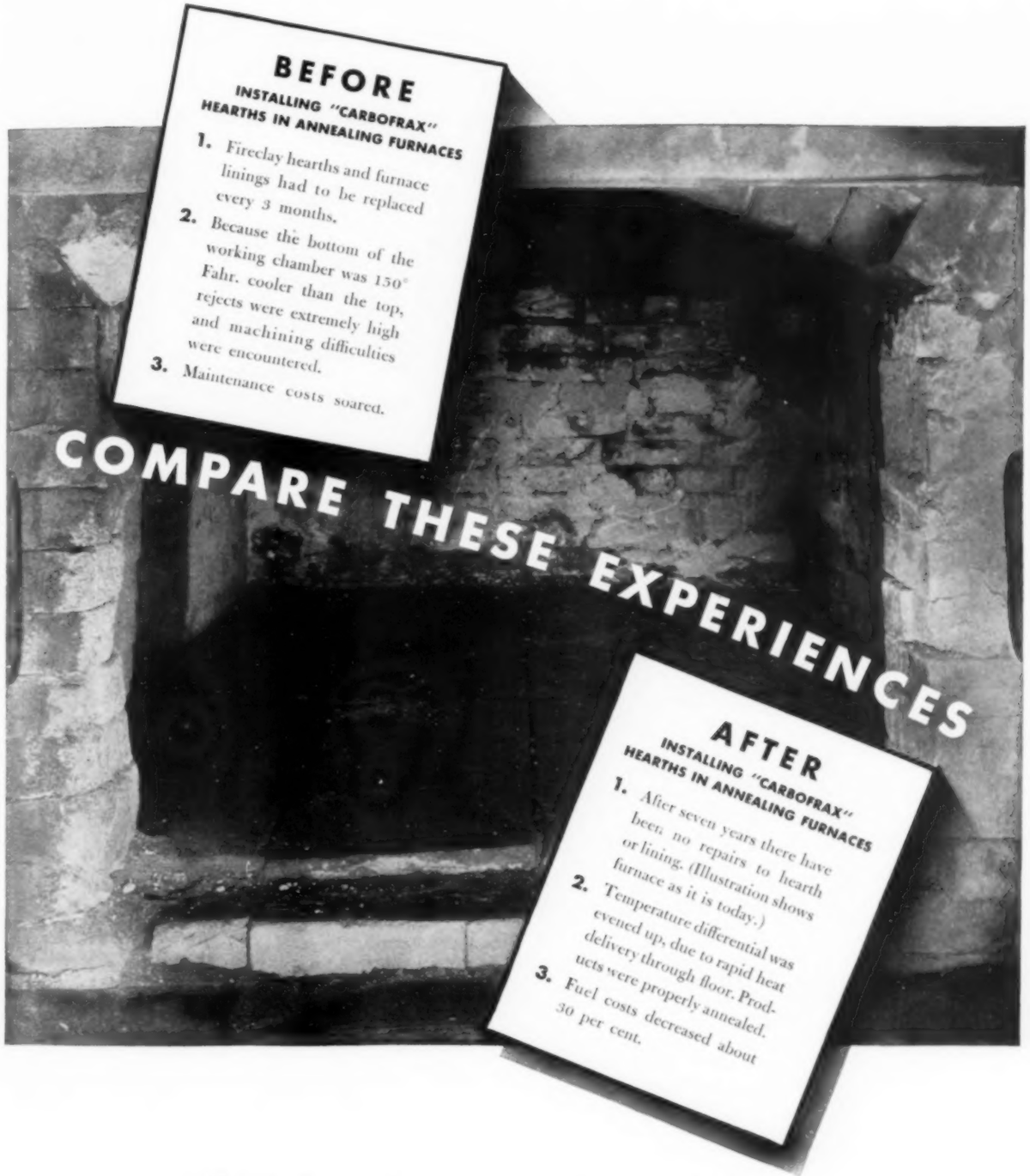
Cast Red Brass, C. M. Saeger, Jr., Foundry, July, p. 18 . . . . Melting and Casting of Special Brass Alloys L. S. Ivanoff, Metal Industry (British), July 6, p. 7 . . . . Magnesium-Chromium as a Deoxidizer of Copper, Charles Vickers, Metallurgia, June, p. 43 . . . . Developments in Brass Die-Casting Methods, Herbert Chase, Machinery, July, p. 653.

Internal Pressure Stress in Lead Pipes, Heinz Bablik, Metal Industry (British), July 6, p. 3 . . . . Extrusion of Lead Sheath, H. R. Simonds, Iron Age, July 19, p. 18 . . . . Impurities in Type Metals, H. V. White, Bulletin No. 17, Virginia Polytechnic Institute.

Stainless Steels

Inclusions in Stainless Steel, M. Baeyertz, Transactions, American Society for Metals, July, p. 625 . . . . Polishing and Etching of High Chromium-Iron Alloys

(Continued on page 50)


BEFORE
INSTALLING "CARBOFRAX" HEARTHS IN ANNEALING FURNACES
1. Fireclay hearths and furnace linings had to be replaced every 3 months.
2. Because the bottom of the working chamber was 150° Fahr. cooler than the top, rejects were extremely high and machining difficulties were encountered.
3. Maintenance costs soared.
COMPARE THESE EXPERIENCES
AFTER
INSTALLING "CARBOFRAX" HEARTHS IN ANNEALING FURNACES
1. After seven years there have been no repairs to hearth or lining. (Illustration shows furnace as it is today.)
2. Temperature differential was evened up, due to rapid heat delivery through floor. Products were properly annealed.
3. Fuel costs decreased about 30 per cent.

THIS is the experience of a famous New England tool manufacturing plant. Other users report similar advantageous results. Perhaps our engineers can be useful to you.

"CARBOFRAX"

REG. U. S. PAT. OFF.

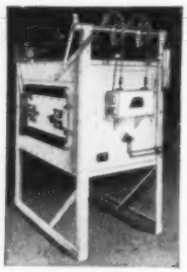
The Carborundum Brand Silicon Carbide Refractory

BRICK · TILE · MUFFLES · HEARTHS · CEMENT

THE CARBORUNDUM COMPANY (Refractory Division) Perth Amboy, N. J. District Sales Branches: Chicago, Cleveland, Detroit, Philadelphia, Pittsburgh. Agents: L. F. McConnell, Birmingham, Ala.; Christy Firebrick Company, St. Louis; Harrison & Company, Salt Lake City, Utah; Pacific Abrasive Supply Co., Los Angeles, San Francisco, Seattle; Denver Fireclay Co., El Paso, Taxas; Williams and Wilson, Ltd., Montreal-Toronto, Canada. (Carborundum and Carbofrax are registered trade marks of The Carborundum Company).

2,000 fine hobs value $50.00 each

hardened in a single month by this "CERTAIN CURTAIN" team!



PRE-HEAT

HARDENING

4000 lbs. per 16-hr. day

A large mid-west manufacturer of tools for the automotive industry reports an output of 4000 lbs. per 16-hr. day of high speed tools from his "team" of Certain Curtain LR-80 Pre-heat and HG-70 High Speed Hardening Furnaces. Part of a recent month's production consisted of 2000 fine hobs with an average value of $50 each.

45c per hr. for current and upkeep

Records show the combined current and upkeep costs for the two furnaces to be within 45¢ per production hour, a splendid example of the efficiency of the electric furnace.

High quality - fast production - low cost

The biggest advantage you gain in using Certain Curtain Furnaces is quality: the working properties of the steel are developed to their fullest extent, while danger of decarburization, scaling, pitting and grain growth is eliminated by the protective Certain Curtain atmosphere in the heating chamber. As a further direct result of perfected atmosphere control, you obtain this superior quality at extremely fast rates of production. This means low labor cost as well as low operating cost.

Certain Curtain Furnaces are made in styles and sizes for heat treating all types of tool steels. We shall be glad to send you literature.

Write for new Bulletins: No. 102 on Hardening, No. 202 on Pre-heating

C. I. HAYES, Inc.

129 BAKER STREET, PROVIDENCE, R. I.

E. F. BURKE
2281 Scranton Road
Cleveland, Ohio

L. W. HAYDEN
26 So. Fifteenth St.
Philadelphia, Pa.

F. J. CONDIT
148 Crestwood Ave.
Buffalo, N. Y.

R. G. HESS
176 Fulton St.
New York, N. Y.

L. C. LOSHBOUGH
2626 W. Washington Blvd.
Chicago, Ill.

C. A. HOOKER
202 Forest Ave., Royal Oak
Detroit, Mich.

ELECTRIC CERTAIN CURTAIN FURNACES

ARTICLES WORTH READING

J. R. Vilella, Paper for American Society for Testing Materials . . . . Stainless Steel in Aircraft Construction, Fredric Flader, Trasactions American Society of Mechanical Engineers, May, p. 295 . . . . Shot-Welded Stainless Steel, Product Engineering, July, p. 242 . . . . Arc Welding Stainless Steel, H. W. G. Hignett, Welder, May, p. 181 . . . . Welding Stainless and Stainless-Clad Steel, W. J. Wachowitz, Iron Age, July 12, p. 41 . . . . Stainless Surfaces for Chemical Plant, J. Hinde, Chemical Age, July 7, Metallurgical Section, p. 6.

Effects of Cold Rolling on Intergranular Corrosion, E. C. Rollason, Paper for British Iron & Steel Institute.

High Temperature Tensile, Creep and Fatigue of Cast and Wrought 18-8, H. C. Cross, Transactions, American Society of Mechanical Engineers, July, p. 533.

Heat Treating

Heat Treatment of Carbon Tool Steel, J. C. Alexander, Mechanical World, June 15, p. 578 . . . . Effect of Heat Treatments on Die Steels, T. Murakami, Iron Age, July 5, p. 22 . . . . Heat Treatment of Alloy Tool Steels, J. C. Alexander, Machinery (British), July 5, p. 418 . . . . Hardening of Rock Drill Steel, L. E. Elvey, Mining Magazine, June, p. 329.

Quenching Media for Steel, Howard Scott, Transactions, American Society for Metals, July, p. 577 . . . . Salt Bath Quenching, Bernard Thomas, Heat Treating & Forging, June, p. 285 . . . . Salt Bath for Heat Treating Duralumin, F. H. Trembly, American Machinist, July 18, p. 497.

Aging Changes in Nitrided Steel, E. G. Herbert, Engineering, June 29, p. 745 . . . . Effect of Notches on Nitrided Steel, J. B. Johnson, Metals & Alloys, June, p. 129.

Bright Annealing of Steel in Mixed Gas Atmospheres, A. L. Marshall, Transactions, American Society for Metals, July, p. 605.

Insulating Firebrick in Steel Heating Furnaces, M. J. Terman, Iron and Steel Engineer, June, p. 218 . . . . Rim-Element Electric Furnaces for High Temperatures, H. Masukowitz, Metal Industry (British), July 6, p. 11.

Corrosion

Report of the Corrosion Committee, Engineer, June 22, p. 639 . . . . Effect of Surface Finish on Initial Corrosion, L. J. Waldron, Paper for American Society for Testing Materials . . . . Corrosion of Metals by Phenols, Metallurgia, June, p. 36.

Some Factors Involved in Soil Corrosion, E. R. Shepard, Industrial & Engineering Chemistry, July, p. 723 . . . . Use of Data on Soil Corrosion in Design of Pipe Lines, K. H. Logan, Paper for American Society for Testing Materials.

Corrosion of Condenser Tubes, Mechanical Engineering, July, p. 439 . . . . Mechanism of Dezincification of Brass, C. W. Stillwell, Industrial and Engineering Chemistry, July, p. 740.

Accelerated Tests of Paints for Steelwork, W. P. Digby, Engineer, June 15, p. 610.

Tests and Equipment

Effect of Size of Specimen on Results for Structural Steel, Inge Lyse, Paper for American Society for Testing Materials . . . . Accurate Strain Measurements, R. L. Templin, Paper for American Society for Testing Materials. *(Continued on page 51)*

ARTICLES WORTH READING

High Speed Fatigue Test, G. N. Krouse, Paper for American Society for Testing Materials.

Interpretation of Creep Tests, P. G. McVetty, Paper for American Society for Testing Materials . . . . Furnace for Creep Testing, H. Montgomery, Metals & Alloys, June, p. 127.

Huggenberger Tensometer, R. W. Vose, Paper for American Society for Testing Materials . . . . A Three-Ton Testing Machine, J. L. M. Morrison, Engineer, June 22, p. 626 . . . . Two New Universal Microscopes, Metallurgia, June, p. 55 . . . . Laboratory Tube Furnaces, F. A. Westbrook, Heat Treating & Forging, June, p. 301.

Uses for Steel

Steels Used on Golden Gate Bridge Construction, C. W. Horack, Western Machinery & Steel World, June, p. 179 . . . . Special Steels for Shipbuilding, A. Lamsley, Heat Treating & Forging, May, p. 222 . . . . Steels in General Shop Practice, F. J. Allen, Heat Treating & Forging, May, p. 237 . . . . Materials Used in Grinding Machinery, Steel, June 4, p. 37.

Metal Work in "the New Architecture," Metal Industry (British), June 1, p. 555 . . . . Steel for Small Houses and Service Stations, Steel, June 4, p. 30, 34, 35 . . . . Manufacture of Lighting Fixtures, Metal Industry, June, p. 208.

Choice of Gear Steels, Machine Design, June, p. 33 . . . . Steels for Heat Treated Gearing, T. R. Rideout, Western Machinery & Steel World, July, p. 201 . . . . Valve Seat Wear, C. G. Williams, Automobile Engineer, June, p. 219 . . . . Cylinder Wear, Automobile Engineer, June, p. 229 . . . . Manufacturing Knee-Action Spring Suspensions, A. H. Allen, Steel, June 18, p. 31.

Progress and Trends in Pipe Line Systems, F. H. Love, Petroleum Engineer, Midyear, p. 43.

Theoretical and Scientific Studies

Late Developments in Microscopy, F. F. Lucas, Journal of the Franklin Institute, June, p. 661.

Solubility of Carbon in Iron-Manganese-Silicon Alloys, C. H. Herty & M. B. Royer, Bureau of Mines, Information Circular 3230.

Terminology Relating to Non-Metallic Elements in Metals, T. D. Yensen, A.I.M.E. Tech. Pub. No. 555, Metals Technology, June.

Magnetic Properties of Iron, D. C. Gall, Journal of the Institution of Electrical Engineers, May, p. 453.

Periodic Structures in Metals and Alloys, L. Northcott, Metal Industry (British), June 8, p. 581 . . . . The "Single Crystal" State of Metals, H. C. H. Carpenter, Bulletin of the Institution of Mining & Metallurgy, June, p. 13.

Magnetic Investigation of the Amount of Retained Austenite in Quenched Steels, M. Mikami, Science Reports of the Tôhoku Imperial University, May, p. 213 . . . . Magnetic Susceptibilities of Solid Solutions of Nickel in Copper, W. H. Ross, Physical Review, July 1, p. 46 . . . . Relation Between Magnetic Susceptibility and Elastic Stress, Yuzuru Watase, Science Reports of the Tôhoku Imperial University, May, p. 208.

Electrochemical Behavior of the Tin-Iron Couple in Dilute Acid Media, T. P. Hoar, Transactions of the Faraday Society, June, p. 472.

Electrical Resistance of Thin Films of Nickel, R. C. L. Bosworth, Transactions of the Faraday Society, July, p. 549.

The Thermal Conductivity of Tool Steels, Denzaburo Hattori, Paper for British Iron & Steel Institute.

"This complete and authoritative volume."
—H. W. Gillett in *Metals & Alloys.*

THE BOOK
OF
STAINLESS
STEELS

Corrosion Resisting and
Heat Resisting Chromium Alloys

Nothing But
Laudatory Reviews!

"For such an ambitious undertaking this book might have been called 'The Book of Knowledge of Stainless Steels.'. The aggregate experience, largely practical, here recorded by 75 experts is enormous."—Leslie R. Bacon, *Journal*, Franklin Institute.

"Until the present there has been no book affording a comprehensive picture of American practice and usage. Mr. Thum, the editor, is to be heartily congratulated for having performed a real service to fabricators and consumers of stainless."—*American Machinist.*

"All About the Chromium Steels! This book is literally an encyclopedia."—Bradley Stoughton in *Mining and Metallurgy.*

"A full treatment of the subject of stainless steels and the associated acid and heat resisting alloys demands wide experience, and much specialized knowledge. In this book such a full treatment is attempted. Briefly, it may be said that for the most part the matter presented is of a high order and the book will have an important place in technical literature."—*The Metallurgist*, Supplement to The Engineer (London).

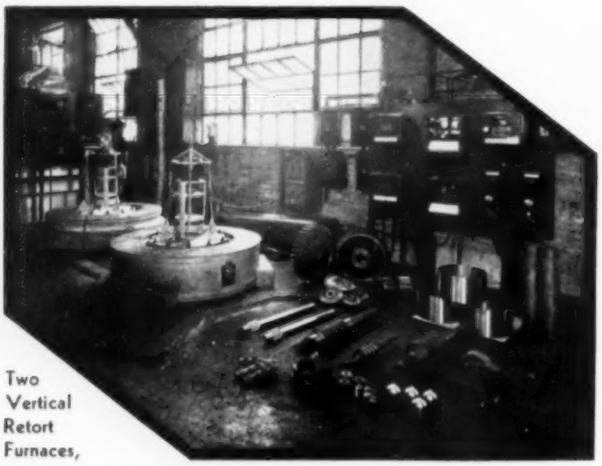
Price $5.00

American Society for Metals

ELECTRIC FURNACES

ASTONISHING

FLEXIBILITY—
ECONOMY—
QUALITY



Two Vertical Retort Furnaces, Carburizing — Nitriding — Annealing — Drawing — at Lindberg Steel Treating Co., Chicago.

IN the flexibility of heat treating equipment, making it useable in numerous processes, lies exceptional economy in plant operations.

Hevi-Duty Vertical Retort Furnaces have this flexibility; effect economy with high quality. In Carburizing the cost is lowered to less than one-half that of pack carburizing. In the Nitriding process the total time is reduced. In Annealing and Hardening, controlled Atmosphere is applied. These characteristics are combined with certainty of high quality products. These features invite your immediate investigation. Just ask for Bulletin No. 930.

TRADE MARK
HEVI DUTY
REG. U. S. PAT. OFF.

HEAT TREATING FURNACES
ELECTRIC EXCLUSIVELY

HEVI DUTY ELECTRIC CO.
MILWAUKEE, WIS.

ARTICLES WORTH READING

Welded Joints & Design

Spheres for Joining Tubes, A. F. Burstall, Product Engineering, July, p. 261 . . . . Steel Making as Applied to Welding, H. Bull, Welding Journal, June, p. 166 . . . . High Quality, High Speed Oxy-Acetylene Welding, A. B. Kinzel, Welding Industry, June, p. 145 . . . . Effect of Welding Current on the Fatigue Strength of Welds, C. H. Jennings, Journal American Welding Society, June, p. 7 . . . . Stresses in Fusion Joints, E. G. Coker, Journal American Welding Society, June, p. 26 . . . . The Welded Edge, F. Leverick, Welder, May, p. 166.

Welding Rod Coatings, L. G. Bliss, Welding, May, p. 203 . . . . Patents on Welding Rod Coatings, L. G. Bliss, Welding, June, p. 242.

Oxy-Acetylene Cutting of Structural Steel, H. H. Moss, Journal American Welding Society, June, p. 8 . . . . Oxy-Acetylene Welding and Metal Cutting, Welding Industry, June, p. 131 . . . . Kinematics of Oxy-Acetylene Welding, R. Granjon, Welding Industry, June, p. 149 . . . . Bronze Welding With the Oxy-Acetylene Flame, A. B. Kinzel, Welding Industry, June, p. 153 . . . . Welding of Structural Nickel Steel, W. L. Warner, Journal American Welding Society, June, p. 15.

Important Happenings in Resistance Welding, P. W. Fassler, Industry & Welding, June, p. 18.

Hard Facing, C. H. S. Tupholme, Metal Industry (British), May 25, p. 531 . . . . Wear Resisting Materials for Coke Handling Equipment, American Gas Journal, June, p. 31 . . . . The Blowpipe for Surface Hardening, A. E. Shorter, Welding Industry, June, p. 158 . . . . Hard Facing, Inserts and Plating Satisfy Hardness Requirements, A. F. Clark, Machine Design, June, p. 29 . . . . Hard Faced Machine Parts, Don Llewellyn, Welding, June, p. 249.

Welding Equipment

Selection and Use of a Welding Plant, Gas Engineer, June, p. 292 . . . . Selecting Electric Welding Equipment, A. M. Candy, Railway Electrical Engineer, June, p. 121.

Portable Welding Unit for Pipe Line Repair, L. G. E. Bignell, Oil & Gas Journal, June 7, p. 14.

Three-Phase Current Welding, E. Luck, Welding Industry, May, p. 104.

Multiple Spot Welder for Automobile Bodies, H. W. Roth, Iron Age, June 21, p. 22 . . . . Electric Resistance Welding Machines, C. A. Hadley, Welding Journal, June, p. 173.

X-Ray Technique for Weld Examination, R. R. Lynn, Mechanical World, June 22, p. 602 . . . . X-Raying 40,000 Feet of Welding at Boulder Dam, R. G. Skerrett, Power Plant Engineering, July, p. 316 . . . . X-Ray Inspection of Heat Exchanger Shells, N. L. Mochel, Iron Age, June 28, p. 10.

Welded Structures

Manufacture of Welded Refrigerator Cabinets, F. L. Prentiss, Iron Age, June 7, p. 12 . . . . Welded Sky-Scraper in Poland, Stephen Bryla, Journal, American Welding Society, May, p. 26 . . . . Welding of Gates for Boulder Dam, C. H. Jennings, Journal, American Welding Society, May, p. 17 . . . . Constructing the Bouquet Canyon Pipe Line, H. A. Van Norman, Civil Engineering, June, p. 306.

Chevrolet Uses Special Equipment to Make Wire Wheels, Iron Age, May 24, p. 16.

Quenching *of* Steel

. . . an answer to your problems

By **HERBERT J. FRENCH**
late of the Bureau of Standards, now with International Nickel Company.

THIS book is a comprehensive discussion of cooling characteristics of various cooling media (coolants). Cooling properties are given for both surface and center cooling of a given mass of steel. Data for center cooling are summarized graphically and in equations which permit computation of center characteristics of various sizes and shapes of steel.

172 pages, 6 x 9, 105 illustrations . . . bound in red cloth.

$2.50

Mail Your Order Today

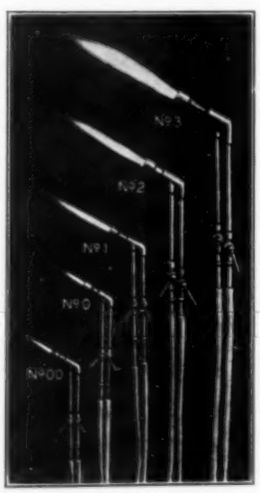
AMERICAN SOCIETY *for* METALS

7016 Euclid Avenue Cleveland, Ohio

Super-Blowpipes

for

Soft Soldering
Hard Soldering
Brazing
Preheating for Welding
Annealing
Hardening
Tempering
Glass Bending
Laboratory Work



for

City Gas
Natural Gas
Mixed Gas
Propane
Butane
Gasoline Gas
Etc.

These Super Blowpipes, because of features inherent in the design, have an extremely wide range of operation.

WRITE FOR MORE INFORMATION

AMERICAN GAS FURNACE COMPANY
ELIZABETH, NEW JERSEY

Something About *Distortion*

DISTORTION—a vital problem among the many problems of the metallurgist—is usually charged to quenching methods. For when a piece of steel is heated in thirty minutes and cooled in thirty seconds, the latter operation seems so drastic that it is there the operator looks for his trouble.

Investigations recently conducted with new precision instruments on distortion in gears have indicated that steel goes out of shape in the heating rather than the quenching. This was determined by reducing the heating rate until the distortion was eliminated, the quenching method being unchanged. These results confirm the beliefs of many metallurgists. The explanation advanced is as follows:

When steel is heated, the outer portion is hotter than the inner portion and, therefore, weaker. As the stronger inner core changes in shape, due to difference in temperature caused by too rapid heating, the weaker outside portions distort.

On the other hand, when steel is quenched properly, the outside case cools very rapidly and "sets" into the shape in which it entered the quench. Any tendency for the inside portion to "go places" is successfully resisted by the strong outer shell.

The above is still a *theory*. The *fact*, however, is that the proper "rate of heating" reduces distortion. The LINDBERG CONTROL provides the operator with a positive control on that important "rate of heating."

LINDBERG STEEL TREATING CO.
221 UNION PARK CT. CHICAGO, ILL.

FREE HELPFUL BOOKLETS

Localized Treating

American Gas Furnace Co. offers information on production machines for localized hardening, tempering or annealing of tools, saws, springs, screws and machine parts of all kinds, using gas as fuel. Bulletin Ag-11.

Nickel Cast Iron's Uses

The role of nickel and nickel-chromium cast iron parts in such applications as fabricating sheet metal, pressing and forging is interestingly explained in a new pamphlet of International Nickel Co. Bulletin Ag-45.

Roll Grinding

Carborundum Co. has published a 50-page handbook on roll grinding containing a great store of information on this subject. Carefully written and illustrated, this treatise has real practical value. Bulletin Au-57.

New Furnace Control

A new and unusual instrument for controlling heating rate of electric furnaces is announced by Lindberg Steel Treating Co. An interesting folder tells how this device "turns down the heat" on any size electric furnace. Bulletin Ar-66.

Copper Welding Rods

American Brass Co. describes in complete detail the welding properties and individual characteristics of 14 different copper alloy welding rods. The 16-page booklet also makes specific recommendations of welding procedure. Bulletin Je-89.

Thermit Welding

Metal & Thermit Corp. offers a new booklet showing all the possibilities of Thermit welding, explaining the action, and telling in detail how representative Thermit welds can best be made. Well illustrated and clearly written. Bulletin Ar-64.

Controlled Steels

Carnegie Steel Co. has published a very interesting booklet which describes in some detail the process control used in the production of uniform steels. Bulletin Je-85.

Heat Resisting Alloys

Authoritative information on alloy castings, especially the chromium-nickel and straight chromium alloys manufactured by General Alloys Co. to resist corrosion and high temperatures, is contained in Bulletin D-17.

Bright Annealing

Electric Furnace Co. tells about their controlled atmosphere furnaces for continuous deoxidize annealing, bright normalizing and annealing ferrous and non-ferrous metals. Work comes clean, bright and dry from these furnaces. Bulletin No-30.

Homo Tempering

Leeds & Northrup Co. introduces a specialized Homo furnace for tempering heavy, dense loads of small particles. Production can be multiplied as much as four times. Complete description is given in Bulletin Je-46.

Atmosphere Furnaces

An interesting folder of Service Combustion Corp. gives performance data on their atmosphere furnaces in actual production bright annealing of ferrous and non-ferrous metals and carburizing, nitriding, forging and hardening without scale. Bulletin De-51.

X-Rayed Alloy Castings

Electro Alloys Co. describes their X-Ray inspection of Thermalloy heat resisting castings for high temperature work. Considerable data on the use of X-Ray tubes and "radon" capsules to check foundry practice are presented. Bulletin Oc-32.

High Strength Steel

Cromansil steel, a development of Electro Metalllurgical Co., has high strength and good ductility "as rolled" and is thus fine for structural applications where its great strength saves much dead weight. Bulletin Je-16.

Cold Drawn Shafting

Union Drawn Steel Co. has an interesting and attractive booklet on cold finished shafting. The complete story of its manufacture is told, and recommendations for specific applications are given. Bulletin Ar-83.

18-8 Steels

Republic Steel Corp. has prepared a new 16-page booklet giving up-to-the-minute data on Enduro 18-8 stainless steels including their several special analyses. Authentic metallurgical and fabricating information is given. Bulletin Je-8.

Plating Manual

The R. & H. Chemicals Department of du Pont has issued an excellent operating manual for plating copper, brass, bronze, and zinc with du Pont copper and zinc cyanides. Full of valuable ideas. Bulletin Jy-29.

Heat Treating Manual

A folder of Chicago Flexible Shaft Co. contains conveniently arranged information on heat treating equipment for schools, laboratories and shops, and also illustrates the several types of Stewart industrial furnaces. Bulletin Ar-49.

Electric Furnaces

The electric furnaces made by Hoskins Mfg. Co. are well presented in their latest catalog. Contents include data on 17 types of furnaces and some valuable information on Chromel resistance wires and thermocouples. Bulletin Sp-24.

X-Rays in Industry

General Electric X-Ray Co. has available a profusely illustrated brochure which gives the complete story of the industrial applications of X-Rays, the modern inspection tool. Bulletin Ma-6.

Quenching Handbook

E. F. Houghton & Co. have published an excellent 80-page handbook on the subject of quenching. More than 30 charts and photomicrographs help tell the story. A copy will be sent free to those who request it. Bulletin Jl-38.

Hardness Testing

Men interested in hardness testing may find it worth while to read the recent catalog of Wilson Mechanical Instrument Co. which describes the latest design of Rockwell hardness testers and auxiliary work supports. Bulletin Sp-22.

Testing with Monotron

Shore Instrument & Mfg. Co. offers a new bulletin on Monotron hardness testing machines which function quickly and accurately under all conditions of practice. Bulletin Je-33.

Structural Bronze

Olympic Bronze, a high copper alloy containing silicon and zinc, is suggested by Chase Brass & Copper Co. for structural and engineering purposes. A new booklet gives many interesting details about its use. Bulletin M-59.

Steel Specifications

A handy, up-to-date specification sheet for carbon and alloy steels is offered by Timken Steel & Tube Co. On one page are printed analyses of all important types of Timken steels. Bulletin Jy-71.

Big-End-Up

Gathmann Engineering Co. briefly explains the advantages of steel cast in big-end-up ingots, showing the freedom from pipe, excessive segregation and axial porosity. An 82% ingot-to-bloom yield of sound steel is usual. Bulletin Fe-13.

Carburizing Boxes

Driver-Harris Co. devotes a folder to Nichrome cast carburizing boxes. Physical properties at room temperature and under operating conditions are given, as are the advantages of Nichrome castings for such service. Bulletin Jr-19.

Sheffield Steels

Wm. Jessop & Sons, Inc., have a booklet which tells why a special anneal and a proper balancing of carbon, manganese and tungsten combine to make Sheffield Superior oil hardening steel non-distorting and easily machinable. Bulletin Jn-61.

Pickling Inhibitors

A pamphlet describing the nature and use of Grasselli Inhibitors is offered to those interested in pickling. A feature is a table of inhibitor strengths recommended for pickling various steels. Bulletin Ap-95.

Metals Under Heat

Leitz Dilatometers for the thermal analysis of metal record photographically seven different curves showing the action of metals under heat. A most interesting pamphlet gives full details of this important metallurgical instrument. Bulletin M-47.

Induction Furnaces

A publication of Ajax Electrothermic Corp. tells of the development, operation and uses of commercial Ajax-Northrup coreless induction furnaces energized by motor generator sets. Bulletin Jr-41.

Heat Controller

As a companion instrument to their new indicating pyrometer, Foxboro Co. has introduced a new and inexpensive temperature controller which is dependable and easy to operate. Close control of temperatures is possible. Bulletin Mr-21.

Stainless Steel Facts

Carpenter Steel Co. offers (to manufacturers in U.S.A. only) a booklet, designed in handy file folder form, presenting a wealth of data on Carpenter stainless steels. A good reference source of material. Bulletin De-12.

Uses of Molybdenum

Climax Molybdenum Co. offers a useful 50-page booklet showing the benefits conferred by alloying molybdenum with iron and steel. The engineering data presented are made clear by many tables and illustrations. Bulletin Au-4.

Oxwelding Stainless

Linde Air Products Co. has published a handbook of instructions for successfully welding corrosion resisting steels by the oxy-acetylene process. Welding procedures and weld treatments are carefully explained. Bulletin Jy-63.

New Tempering Furnace

American Electric Furnace Co. has a new, low-priced electric air tempering furnace. It heats to 600° F. in 5 min. and to 1000° F. in 15 min., transferring heat to work 50 times faster than still air and 6 times faster than salt. Bulletin Mr-2.

Optics in Metallurgy

Many uses for optical instruments in metal working are described in a new booklet of Bausch & Lomb Optical Co. Photomicrography is prominent, but this well illustrated booklet shows many other interesting optical instruments. Bulletin No-35.

Blast Cleaning

A rugged blast cleaning cabinet for rapidly cleaning small work is described in a recent folder of Pangborn Corp. Full information on the operation of this machine is presented; many drawings and pictures are included. Bulletin Je-68.

Air for Furnaces

Users of gas or oil-fired furnaces know the necessity for a dependable source of large volumes of air at low pressures. A generously illustrated folder of Spencer Turbine Co. shows why their Turbo-Compressors give unfailing, economical air service. Bulletin Mr-70.

11 Stainless Steels

Pertinent facts on 11 different types of Bethadur and Bethalon corrosion resisting steels are presented in a 40-page Bethlehem Steel Co. booklet. Advantages and limitations of each type are frankly presented. Bulletin Fb-76.

Manual of Pyrometry

Brown Instrument Co. offers an elaborate manual which describes the 50 exclusive features of their potentiometer pyrometer. The book will greatly interest those who must maintain accurate temperature. Bulletin Jr-3.

Cast Vanadium Steel

Jerome Strauss and George L. Norris have written a technical booklet for Vanadium Corp. of America describing the properties developed by steel castings containing various percentages of vanadium. Bulletin S-27.

Carbonol Process

The Carbonol process of carburizing is described in detail in a folder of Hevi Duty Electric Co. Results are said to be quicker, cleaner and better cases at very low cost. Bulletin Jy-44.

Hardening at 2500°F.

C. I. Hayes, Inc., describes their Certain Curtain electric furnace for hardening alloy and high speed steels in the range 1850-2500° F. Emphasis is laid on the features of Hayes Certain Curtain atmosphere control. Bulletin Jy-15.

Kanthal Alloys

S.K.F. Steels, Inc., offer a descriptive booklet on Kanthal alloys. Certain of these alloys may be used as resistance elements; others are for furnace parts or other heat resisting applications. Full details are given in Bulletin Je-78.

Non-Ferrous Annealing

General Electric Co. describes bell-type furnaces for annealing non-ferrous metals in a new folder which gives many data on operation and performance. Description is from technical rather than sales angles. Bulletin Ar-60.

Metal Progress
7016 Euclid Ave., Cleveland

Please have sent to me without charge or obligation the following Literature described in the August issue. (Please order by number only.)

.....

.....

.....

Name .....

Position .....

Firm .....

Address .....

Eliminate
NEEDLESS HEAT
IN YOUR HEAT TREAT
DEPARTMENT THIS SUMMER

NON BURNING
CHAR
CARBURIZERS

WILL NOT BURN EVEN
WHEN DISCHARGED
DIRECTLY INTO THE AIR
IN DIRECT QUENCH OR ROTARY PRACTISE

CHAR PRODUCTS COMPANY
MERCHANTS BANK BUILDING INDIANAPOLIS

Columbia
TOOL STEEL

For thirty years (since August 4, 1904) this company has been serving tool steel users who have wanted the very best that could be made.

It pays to use Good Tool Steel.

COLUMBIA TOOL STEEL COMPANY
MAIN OFFICE AND WORKS
500 E. 14TH STREET, CHICAGO HEIGHTS, ILLINOIS

BEAUTY IN DESIGN

(Continued from page 25.)

Not only is the form of a product important, but also its color appeal. We have come to associate the combination of white and blue with cleanliness and sanitation, red with heat, and green with cold — all derived from the elements which stand for these combinations as water and sky, fire and flame, ice and snow. How important this is can be left to the common experience of each reader. This is important in large structures as well. Artificial light in various colors is capable of most effective ornamental value, if it is installed with this end in view. A striking proof is found any night at the Chicago Fair.

Other materials suitable for the industrial designer's art may be mentioned: More and more we are using new metals not for beautification only, but to add strength without weight, to resist corrosion, and to lessen maintenance. Structural members, if properly designed and embedded into a structure, can become ornaments of plain but striking beauty. Speed may be suggested by careful determination of the lines that follow the wind movement in vehicles, be they ships, trucks or street cars.

There is no end to these possibilities. It is the job of the industrial designer to point out to the manufacturer which of them are of advantage to his product, and which may be economically adapted to it.

It may be objected that the services of such an industrial designer or the establishment of a design laboratory may be beyond the pocketbook of any but the largest corporation. This is clearly refuted by the performance of several independents in industry, firms which have strictly limited financial resources. As a matter of logic it is self-apparent that it is cheaper to get good advice than to make dies, machines, and production facilities for a product which will sell but slowly.

The industrial designer, on his part, has far more than his salary or his fee at stake. Every success adds to his reputation, until it reaches a point where it is a guarantee of quality to affix it to any manufactured product, putting it into a class by itself.

There is no more devastating critic than Mr. Public, and since he has approved the works of many artisans such as Duncan Phyfe, it may well be assumed that he will do so again.

FOR PRECISION AND SPEED IN THE PREPARATION OF METAL SAMPLES FOR MICRO-ANALYSIS

GUTHRIE · LEITZ

Automatic

POLISHING MACHINE

ONE- TWO- and FOUR SPINDLE Models

THE "Guthrie-Leitz" Automatic Polishing Machine is designed to reduce to a minimum all of the various factors through which the preparation of metal samples by hand proves so undependable. By means of a magnetic holding and oscillating device, all elements of human equation are eliminated. With this machine, it is possible to measure the pressure, speed, time, amount of abrasive, etc., thus saving time and labor and making it possible to entrust the preparation of even research samples in the hands of an unskilled operator.

An outstanding feature of these Polishing Machines is that the specimen can readily be removed for examination during operation.

Write for Literature:

Catalog No. 1196 "Guthrie-Leitz" Automatic Polishing Machine

E. Leitz, Inc. DEPT. 560 60 E. 10th ST., NEW YORK

NRA

PROBLEMS *in* HARDNESS TESTING

Solved at Minimum Cost. Our Bulletins Tell How

For 100% portable hardness testing for metals the SCLEROSCOPE is used the world over, described in our bulletins S-22 and S-30.

For testing rubber our bulletins R-4 and R-5.

For testing the Qualitative and Quantitative hardness under the static method of all known materials including dead soft or superhard metals, sub-surface testing, etc., send for bulletins M-3, M-6 and M-7 descriptive of the MONOTRON, now in general use.

A selection from this line will definitely meet with your requirements

THE SHORE INSTRUMENT & MFG. CO.

Van Wyck Ave. & Carll St. Jamaica, New York, N. Y.

MODESTLY SUGGESTS YOU TRY

BLAST CLEANING

HEAT TREATED DIES, GEARS, TOOLS, ETC.

● Scale, rust and dirt quickly and economically removed with Pangborn Blast Cleaning Equipment. A type for every need. . . . *Write to the World's Largest Manufacturers of Blast Cleaning and Dust Collecting Equipment.*

PANGBORN CORPORATION

HAGERSTOWN · · · · MARYLAND

Q-ALLOYS

STAND UP UNDER FIRE

WITHOUT

QUALITY

COMPETITION

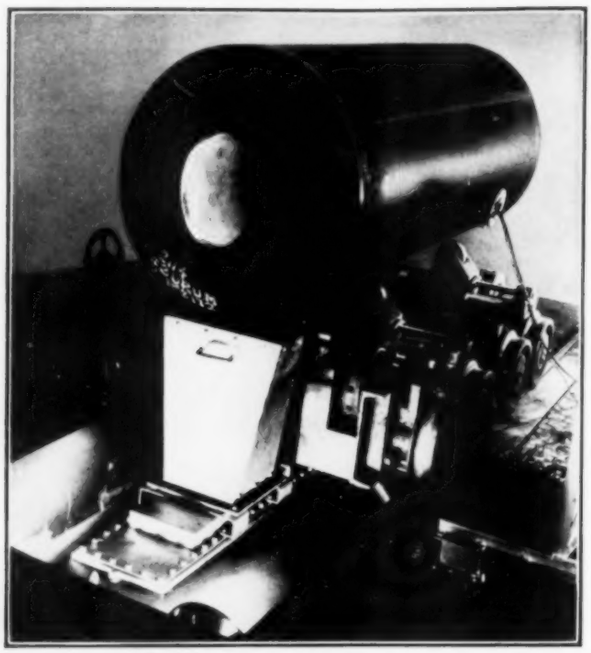
OLDEST and LARGEST EXCLUSIVE MANUFACTURER OF HEAT AND CORROSION RESISTANT ALLOY

CASTINGS

•

GENERAL ALLOYS CO.

BOSTON • CHAMPAIGN



G-E X-Ray Unit O.K.'s the Welds of EDGE MOOR IRON CO.

● Compactly housed in a pit only 12'x4½'x6', this 300,000 volt oil-immersed shook proof x-ray unit is meeting the exacting requirements of the Edge Moor Iron Company in the radiographic inspection of fusion welds in pressure vessels.

This type of installation demonstrates again the flexibility and versatility of General Electric's KXC-1 Industrial X-Ray Apparatus. With all high tension parts, including the x-ray tube, sealed in oil within a single grounded metal "head," it matters not whether it is perched at a high altitude on the rim of a mountain canyon or operated in a pit in the humid atmosphere of the seashore—under any and all conditions the x-ray output is the same, it is *shock proof*, and the standard unit is adaptable to many methods of mounting to suit the particular needs of the purchaser.

Whatever your x-ray requirements, General Electric has apparatus to meet them. Write today for the booklet "Industrial Application of the X-Ray." If you'll outline your problem, descriptive literature on the proper x-ray equipment will also be sent you by return mail.

Address Industrial Department

GENERAL ELECTRIC X-RAY CORPORATION
2012 JACKSON BLVD. CHICAGO, ILLINOIS
Branches in Principal Cities

DENTAL ALLOYS

(Continued from p. 44) which occurs between the tooth and the filling, the amalgam coefficient of thermal expansion being much greater than that of the tooth. During the setting period of 24 hr., there is first a small period of contraction, generally attributed to the solution of the alloy in the mercury. Then an expansion occurs to a maximum, followed by a slight contraction while equilibrium is being established.

Amalgams flow under pressure. Obviously this factor must be kept to a minimum. The allowable flow is 4% in 24 hr. under 3550 psi. load. Undoubtedly tin is the major factor contributing to this property.

The minimum ultimate compressive strength allowed by Federal Specification No. 256 is 35,500 psi. Most modern amalgams average somewhat over 40,000. Ultimate tensile strengths are much lower, but are of little practical importance.

A good amalgam will not corrode in the mouth, but it does tarnish in most cases due to the formation of a silver sulphide.

As might be predicted from the presence of intermetallic compounds, dental amalgams are brittle, and cannot be burnished. Improper contouring by the dentist, with the resulting overhanging and overlapping margins, is the principal cause of failure, assuming a correct preparation of the cavity and manipulation of the amalgam.

Stainless Steels

Stainless steels have been used only recently, and only the "18-8" varieties at all extensively. Probably the reason for this is that the manufacturers of truly stainless steels capable of heat treatment have not entered the field as yet. There are two important dental uses, (*a*) orthodontic wires and springs, and (*b*) full and partial dentures (plates).

For orthodontic work the material is soldered with gold solder, using a mixture of borax, hydrochloric acid, and calcium or sodium fluoride as flux. There is no alloying whatever of the solder and steel so the joints are roughened, and only a mechanical union results.

Stainless steel dentures have much to recommend them. They are strong and light, and their comparatively high thermal conductivity conduces to health of the underlying tissues.

EFFICIENT-ECONOMICAL PICKLING

GRASSELLI 3

INHIBITOR

Guesswork is Costly

THERE IS NO GUESSWORK IN EFFICIENT, ECONOMICAL PICKLING

A GOOD inhibitor, coupled with good pickling practice takes the *guesswork* out of pickling.

Good pickling practice with the use of a good inhibitor insures a saving in acid, a saving in metal loss, an elimination of hydrogen embrittlement, a better finish and improved working conditions.

Grasselli 3 Powder Inhibitor properly used *ELIMINATES GUESSWORK* and assures efficient, economical pickling in your plant.

GRASSELLI STEEL SERVICE

Not a name, but a complete all-around laboratory and plant pickling service . . . maintained for the purpose of servicing our products and your problems. We ask you to make use of it.

THE GRASSELLI CHEMICAL CO., INC., Cleveland, Ohio

Write for Interesting Booklet

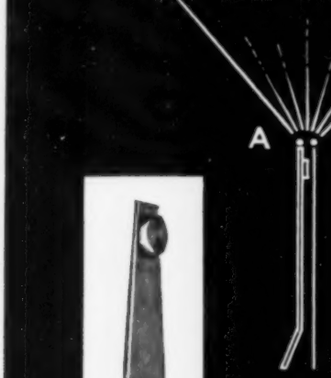
GRASSELLI

GRASSELLI . . . THE ANSWER TO YOUR PICKLING PROBLEM

Whr-r-r-r-r . . .

from A *to* B

2,000,000,000 times!



Vibrator Arm of Beryllium Copper shows *no signs of fatigue-fracture*

IMAGINE *this* test of fatigue resistance! A vibrator arm of *heat treated* Anaconda Beryllium Copper (1 5/8" long, .013" thick, 3/8" wide at one end, and 3/16" at the other) was vibrated at a rate of 230 cycles per second . . . the full movement of the deflection being 1/16". Each reversal involved a stress of 20,000 pounds. During the test, the temperature was varied between 100° and 300°F. *After two billion reversals, no signs of fracture due to fatigue were apparent.*

Beryllium Copper develops remarkable physical properties by heat treatment. For instance, the tensile strength of wire may be increased from about 74,000 p.s.i. in the annealed condition to any desired value up to 181,000 p. s. i. Similar increases are achieved in hardness as well as in fatigue resistance.

Anaconda Publication B-21 describes Anaconda Beryllium Copper in more detail and gives general heat treating instructions. A copy will be mailed on request.

ANACONDA
from mine to consumer

THE AMERICAN BRASS COMPANY
General Offices: Waterbury, Connecticut
Offices and Agencies in Principal Cities
In Canada: ANACONDA AMERICAN BRASS LTD., New Toronto, Ontario

ANACONDA COPPER & BRASS